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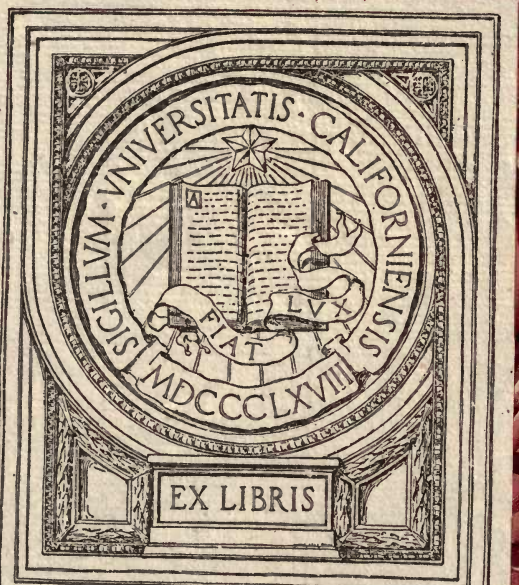

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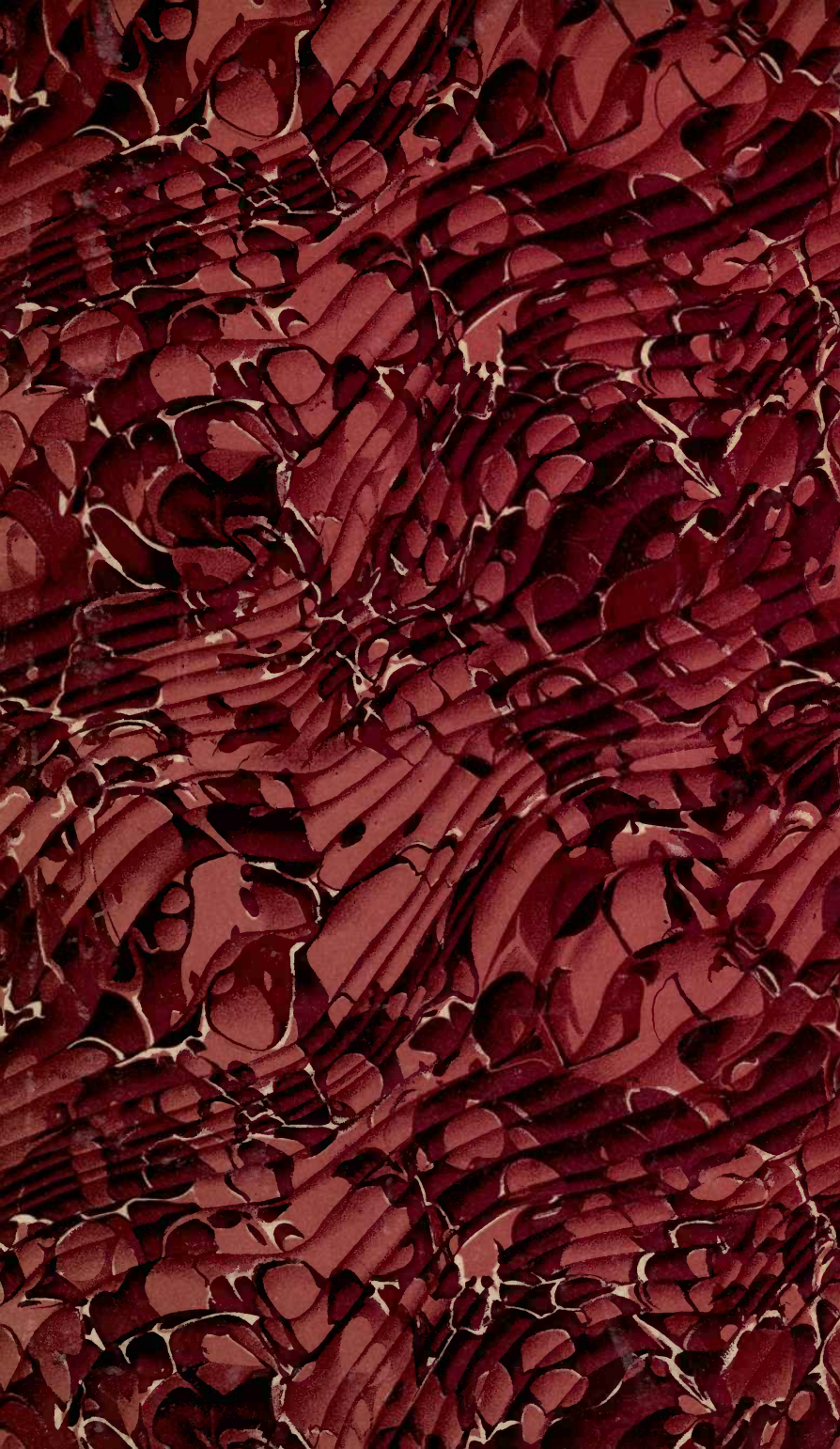

UNIVERSITY OF CALIFORNIA
AGRICULTURAL EXPERIMENT STATION
E. W. HILGARD, DIRECTOR

NATURE-STUDY BULLETINS

BUTTERFLIES

By C. W. WOODWORTH

THE LIVING PLANT

By W. J. V. OSTERHOUT

PUBLISHED BY THE
UNIVERSITY OF CALIFORNIA
BERKELEY

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PREFACE.

The Experiment Station desires to secure the enlistment of many volunteer observers in all parts of the State, and hopes by their coöperation to be able to solve many problems of value to agriculture which it would otherwise be unable to approach. For instance, we desire to determine the chacteristics and boundaries of the agricultural regions of the State, and to do this must learn of the distribution of plants and animals, and their abundance and behavior in every locality. Suggestions of the observations we are trying to make, and desire others to help us make, will be found scattered very abundantly through these bulletins.

For this coöperation we must look to the school rather than to the farm. This Bulletin, therefore, and those that may follow in this series, are addressed to the teachers of future farmers rather than to the farmers themselves. For this reason they will not be distributed to those on the general mailing list of the Station, but will mainly be sent to teachers and others directly interested in nature study. The subject matter will not be directly the immediate problems of agriculture, but rather the underlying principles and the object to be attained; not the direct teaching of useful facts, but the development of the power of discovering these facts for one's self. The development of these powers of observation and judgment will be essential to success in the coming farmer. Those who have interested themselves most deeply in searching for effective means of promoting the agricultural interests of the country, have quite uniformly reached the conviction that the effort must begin with the child. The farmer, of all men, should have an unblunted sympathy and love for nature in all her forms and moods. "The man with the hoe" needs but the love of nature to change his mere existence into a life of hope and joy. In other words, it is preëminently desirable that nature study, which is beginning to

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be so prominent in the best of the city schools, should be still more developed in the country school. Nature study is a very different thing from the natural sciences, as they have usually been taught and considered. The student should be taught to view an insect, for instance, not with the eye of a zoölogist, but rather as a fellow-creature whose life and world thus become objects of sympathetic interest. It is not an object to be dissected or analyzed, but one that lives and influences and is influenced by every other life, object, or force with which it comes in contact.

Teachers generally feel that they are not prepared to give the best instruction in nature study, even though they have given much attention to the various sciences. Fortunately, however, they need but to catch the spirit of the investigator, and nature study teaches itself.

Little or no time need be assigned to this subject on the schedule, since it can be made to contribute its influence to the enriching and brightening of all the work of the school. How this can best be done will always be a problem for each teacher to solve for himself. The suggestions here made are given in the hope that they may aid teachers by pointing out matters for observation and methods of study.

(E. W. H.)

BUTTERFLIES.

By C. W. Woodworth,
Assistant Professor of Entomology.

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THE STUDY OF BUTTERFLIES.

There is so much about insects to excite one's interest that they are peculiarly available for nature study, and among insects the butterflies, by their conspicuousness and beauty, fitly occupy the first of the series of Nature Study Bulletins.

DISTRIBUTION OF BUTTERFLIES.

Habitat.—Almost everyone if asked where butterflies are to be found would answer, everywhere; but on second thought would readily admit that they are by no means uniformily distributed: they may be abundant at one spot and rarely or never found in another situation. We are thus met at the beginning of our study of butterflies with this problem: How can we explain the *habitat* of butterflies, or the preference they exhibit for certain situations? Perhaps after a little thought we may say: Butterflies live on flowers; so that where flowers are, there we will find butterflies. If we begin to study the matter, however, we will very soon see that the facts cannot be so easily accounted for. The same plant may sometimes be present over a great part of the country, and yet a certain kind of butterfly that feeds upon it can be found in only a very limited locality. If we begin to collect butterflies, we will find that there is a certain field or valley, or certain hillside, where we can find a kind of butterfly that we may not see elsewhere. Perhaps there are two or three localities where it occurs, and nowhere in the intermediate regions. The same problem occurs if we begin to study any other animals or

plants; so that in studying butterflies we may learn much that will enable us to understand the distribution of many other forms of life. Sometimes a crop will fail at one place and succeed in another, and we may from these butterfly studies become able to understand why. Much remains yet to be learned about the *habitat* of animals and plants; and it is possible for any one, even a child, to make real contributions to our knowledge of this subject. Butterflies are particularly useful for the study of *habitat*, because they are conspicuous and therefore easily observed.

The study of *habitat* will have to be done out of doors, and will add much to the pleasure of the recess or noon hour; and the recording of observations can be made use of in the writing, language, or drawing exercise following.

A good way to proceed in the study of *habitat* is to make a map of the region studied; it may be the school district or a farm, or some waste land near the school house. On this map mark in blue each place where the butterfly that is studied is to be seen abundantly, and in red those parts which it seems to avoid; then the uncolored places will represent the territory over which it flies, but does not become abundant.

After this is done, a study of the plants, of the elevation, of exposure to the sun and winds, the character of the soil and the moisture contained in it, may give a clue to the reason for the distribution.

Independent work by different pupils, afterwards compared, will assist in getting them to make accurate observations; and studies upon different species of butterflies will aid in overcoming the tendency to reach too hasty and unproved conclusions. Every butterfly will differ somewhat in its behavior and produce problems peculiar to itself; but all will contribute to our knowledge of the principles upon which depend the preferences of these creatures.

Geographical Distribution.—A few kinds of butterflies are to be found over a large part of the world, but most of them are not widely distributed, often being found only in

a few places and perhaps even there rarely. Usually, however, an insect which is rare in one place may be very abundant in another. The study of the geographical distribution of insects is sure to aid in the study of the distribution of other organisms, especially plants. By it we hope to learn how to judge of the adaptability of new localities to any new plant that may be introduced, to know how widely a noxious weed or injurious insect is likely to spread and become troublesome. California is a wonderfully good State for the study of distribution, because we have so many distinct climatic regions. One needs often to go but a few miles to find the insect inhabitants quite different in their relative abundance, and sometimes even they may differ in kind also. The accompanying map of California (Fig. 1, page 10) gives an idea of the principal geographical regions. In a mountainous country like this the elevation is the most important consideration for the division of these regions. The boundaries of the regions are not given because we do not yet know enough about the subject to outline them accurately. Everyone can aid in this study. We want to know in each locality what butterflies are present, what time of the year they are flying, when they become most abundant, and how abundant each kind is as compared with other kinds.

The gathering of these facts will give occasion for the making of many observations on the habits and peculiarities of butterflies, as suggested in subsequent pages of this Bulletin.

It is entirely practicable to attempt a study of the distribution by means of correspondence between schools. The practice in letter-writing would give ample reason for establishing such correspondence; and nothing will contribute more effectively to a practical knowledge of the geography of the State than the attempt to make out the distribution of a butterfly.

Seasons.—We do not see the same kinds of butterflies at different seasons of the year. There is one lot that is with us all winter, and flies every warm day; then there is a set

Fig. 1.—Map of California, showing geographical regions.

that comes out very early in the spring, fresh and bright, contrasting strongly with the dingy, battered winter butterflies; and as spring advances still other forms begin to appear. Thus there is a sort of a procession of butterflies, each kind having its time for appearing and disappearing. Some kinds remain with us but a short time, and a great part of the year are not to be seen at all; others stay with us nearly all the time. A programme or calendar might be made, showing the time of appearance of all the commoner butterflies. This could be kept, and the next year the same species could be watched to see that they all kept their appointments.

There will always be a little difference from year to year, for some seasons are earlier than others, and curiously enough all the kinds will not agree as to whether a season is early or late; so that one year one kind may come at the same time as another, and the next year they may come at different times.

DAILY LIFE OF BUTTERFLIES.

Sleep.—Butterflies invariably go to bed early and get up late; not every day at the same time, but always long before dark the butterflies are all gone, and every early riser will have to wait till the sun is high before he can see butterflies on the wing.

Make out a table like the following, on which to record the observations for a week; the making of the averages will furnish an exercise in arithmetic that will not seem like work.

Date: ——, 1900	Hour when first seen								Hour when last seen							
Name of Butterflies	1	2	3	4	5	6	7	Average	1	2	3	4	5	6	7	Average
Anosia plexippus																
Euvanessa antiopa																
Pieris rapæ																
Etc.																

Observations like these will be of a great deal of value to

the University in the study of agricultural regions, and we would like to receive such tables from all parts of the State.

If one attempts to make a table like that given above, he could increase its value by making a note of the temperature, of the sky—whether cloudy or clear—and as to the dew, fog, or wind, or any other things that might affect their arising or going to bed. Everyone ought to be taught how to read the thermometer, and, if possible, the barometer too, and to make all the usual meteorological observations; for the weather has a great influence on all creatures, whether animal or vegetable.

Many questions will occur to one when trying to observe the sleeping habits of butterflies. Where do the different kinds go when they want to sleep? How do they act when in search of a bed? What is the position of the body and of the various parts of the body after the insect has gone to rest? Does the insect remain perfectly quiet as soon as it finds a sleeping-place, or is it restless, moving about for some time before going soundly to sleep? If it goes to sleep in the afternoon and stays asleep all night, would it be exactly in the same position in the morning that it was in the night, or does it move about in its sleep as we do? How does it act when it is waking up in the morning? All these questions, and a great many more which will suggest themselves, are observations that can be very easily made upon all our commoner butterflies, and each kind of butterfly will probably be found to differ in some respect in his habits from every other species; so the observations must be made on a great many kinds before the subject will be thoroughly understood. Indeed, there may occasionally be a good deal of difference in habits of different individuals of the same species.

Flight.—The sleeping habits are very interesting particulars of the daily life of insects, but the habits during the active life are of even greater interest. No one who has watched the flight of butterflies will have failed to notice how at some times they seem very intent upon feeding upon the flowers; and at other times they seem to

fly with such a quick, nervous movement that it is very difficult to capture them, and they rest only a moment on one flower and then are off to another. At other times they seem to pay no attention to the flowers at all, but sail leisurely back and forth over the fields; sometimes chasing one another, and at other times alighting on bare ground. Probably a great many of these changes of habit are due to the temperature, so it would be well to make observations of the temperature at the same time that these things are observed. It is possible that the readings of the barometer would also give some explanation, and certainly the amount of moisture in the air has a great effect.

It is a pleasant thing to keep butterflies in the school room. Of course, they will stay mostly about the windows, but if the windows contain plants and flowers, as all school rooms should, they will by no means spend all their time fluttering against the glass, and will, by their manner of flight, show evidence of many of the same mental conditions as out of doors.

Manner of Walking.—Some butterflies have six strong legs like other insects, but in many the front pair are very small (Fig. 2) and of no use for walking. Butterflies do

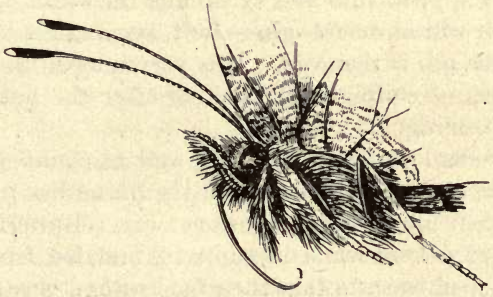

FIG. 2.—Side view of the front part of the body of the butterfly, showing the legs and mouth parts.

not walk much as a rule, especially while being looked at; but if they are kept indoors for some time they seem to become accustomed to people, and will walk about and let one watch them quite closely. Notice the different positions

of the legs in the four-footed kinds. Note that the legs are jointed, and how many of these joints act as feet. Observe how useful are the claws at the end of the foot. Cause the butterfly to walk over a piece of glass and then over a piece of cloth and see the difference. If the butterfly is quiet enough to let you do so without trying to fly, take a slender piece of wire and gently raise the different legs off from the surface on which it is standing, and observe which seems to disturb it most. Allow the butterfly to walk up your finger and notice how it acts when it gets to the top. Many other experiments will readily suggest themselves.

Feeding.—Butterflies that are kept in the school-room should be fed; and then is the best time to study the method whereby each can obtain its food. Provide a little dish containing a thin syrup made of white sugar; then holding the insect carefully by the wings, taking a pin in the other hand and dipping the pin in the syrup so as to slightly moisten it, but shaking off any drop that may form, gently insert the pin about the middle of the coiled-up tongue of the butterfly, and then it can very readily be uncoiled. In uncoiling, some of the sweetened liquid will get upon the tip and be sucked up by the insect; and if the tip is now dipped into the syrup and the butterfly is at all hungry, it will at once begin to feed, keeping the tongue out though the pin is removed. It is very interesting to watch the process of coiling and uncoiling after the butterfly has finished feeding.

After one has done this and is well acquainted with the operation, he may readily see that the butterflies in the field handle their tongues in the same way. Butterflies after being kept a long while in captivity and fed from day to day, will soon learn to take their food without any difficulty, uncoiling their tongues themselves when the food is presented, so that the use of the pin to uncoil it may become unnecessary.

Social Life.—The majority of species at some time during their life become more or less social. This is especially likely to be seen in mid-summer, or towards the fall of the

year; and one may sometimes see swarms of butterflies, often numbering scores or even hundreds, gathering together, particularly in the moist places in the dried-up beds of streams, or in other open bare spaces, where they will remain for hours at a time, now and then flying about and then again alighting in about the same place. These swarms of butterflies are not usually confined to single species, though generally one species is very much more abundant than any other. Late in the fall there is at least one species of butterfly common in this State (*Anosia plexippus*) that has the habit of gathering in immense swarms, reminding one of the swarms of birds that gather at this time of the year preparatory to migrating; and it is thought that in this case the butterflies gather for the same purpose. Aside from the gatherings described above, the social instincts of butterflies seem to be confined to the habit all have of flying after each other during the hotter part of the day, occasionally three or four together. When they are taking their food on the flowers they seem to be annoyed by the presence of other butterflies. The more timid kinds will often leave a blossom at once if another butterfly attempts to alight upon it; but some species do not appear to be so timid, and occasionally two or three will be found busily working upon the same bloom, and paying no attention to each other.

Enemies.—Butterflies, as well as other creatures, have enemies. They are often caught by spider webs, though as they are generally strong enough to tear their way through, they usually get free. It seems that their clothing of scales (Fig. 3) is particularly useful as a defense against spider webs, for the web becomes attached merely to this clothing; as the insect struggles the scales are pulled off and left behind with the web, and the insect escapes, scarcely at all the worse for wear. There is a spider, however, which occurs in the blossoms in some regions, that is able to destroy a large number of butterflies. This spider, taking firm hold of the inner parts of a blossom with its shorter legs, lies in wait for the butterfly, and when it comes to feed suddenly grasps

it with its long legs, holding it fast in spite of all its efforts to escape, and sucking the fluids from the body. After feeding to its satisfaction it drops the dead body of the butterfly to the ground, and is ready to capture the next

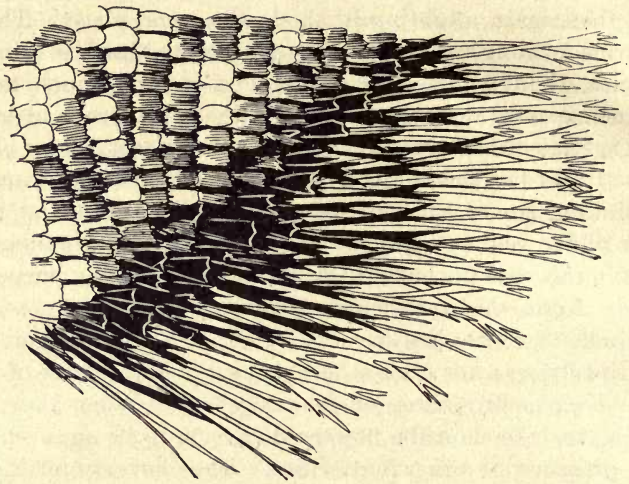

FIG. 3.—The clothing of scales, as seen when a portion of the wing is placed under the microscope.

victim that may come. Butterflies are such active creatures that very few other insects are able to capture them, though a certain number are destroyed when they are young, or getting very old. Birds probably destroy more butterflies than do other animals, and it is thought that much of the color and pattern of the wings often develop as a protection against birds. It is thought, for instance, that the brilliant colors and peculiar patterns of the wings (Fig. 4) catch the attention of the birds which for this reason try to catch the wings; the body of the insect in such a case escapes, and the worst that happens is a small hole torn in

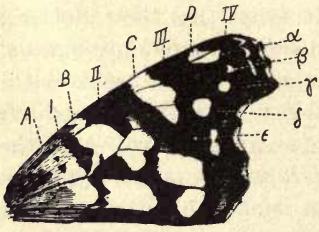

FIG. 4.—Wing of Vanessa, showing system used in naming the various spots.

the edge of the wing. Indeed, one often captures butterflies with broken wings, so torn as to suggest the mistake of some bird. Many butterflies have entirely different patterns on the upper and the under side of the wing, and it is supposed that these differences have been brought about as a means of protecting the insect. A brown butterfly flying along, suddenly becoming gray as it alights, would certainly be very misleading to the bird that was attempting to capture it. One of our commonest butterflies (*Cœnonympha californica*) in the fall of the year is almost white above, but varies from gray to brown below. In addition to the protective color of the under side of the wing, it has developed a mode of flying that is very misleading; the insect in flying appears as though it were falling over and over like a bit of leaf, and finally often, when alighting, lies on its side on the ground.

LIFE-HISTORY OF BUTTERFLIES.

Thus far we have been studying the butterfly only in its full-grown form. Everyone understands that the butterfly is first a caterpillar; indeed there are four distinct stages in a butterfly's life, so different from each other that no one could tell that they come one from the other without actually watching the transformation. The study of these changes is one of the most interesting departments of nature study. The earlier stages of most of our butterflies are still unknown; so that here also there is opportunity for original work.

Most butterflies require just a year to go through their complete transformations, though there are some that have two or even more generations in a year. With most butterflies there will be a time of year when only the caterpillar can be found; then the pupa will be produced, and later the full-grown butterfly; this, after a while, will lay its eggs and die. It is evident that the different kinds of butterflies have a very different annual programme, because there are some kinds always flying whenever it is warm enough. One might draw a diagram for each species, indicating by a

mark of one color, the period in which the egg is found, the time of the life of a larva or caterpillar by another, that of the pupa or chrysalis by a third, and that of the perfect butterfly by a fourth. Of course these periods would overlap each other slightly, since the adult insects live some time after the eggs are laid, and the eggs do not all hatch at exactly the same time.

One could also make a butterfly calendar on this principle, that would indicate not only the time when each common butterfly first appeared in the spring, but also the time of its greatest abundance, by widening the line and narrowing it again towards the time when it disappears.

Almost all butterflies have peculiar habits or structure, or have their life history so arranged that it enables them to pass through the winter; and as in this State we have such long, hot, dry summers, many have special provisions for passing this season. When the insect passes the winter in one of its active forms, the winter rest resembles in many respects the daily sleep of the same insect during the warmer parts of the year. It appears almost as though the butterfly or the caterpillar merely went to sleep too soundly, and so slept on day after day; and in a good part of the State many of these insects that have thus gone into retirement, come forth and fly or walk about during the warmer days. There is one difference between the winter rest and the daily rest of insects; *viz.*, the fact that they seem to select for the former much more secure and secluded places than for ordinary sleep.

Egg-laying.—The eggs of butterflies are usually quite difficult to find, as they are such inconspicuous objects; and the observation of the methods of egg-laying are still more difficult. Each species acts somewhat differently; but if one knows the food plant of the larva, and will persistently follow those butterflies that are seen fluttering about that plant, he may be able to observe the process. The easiest kind to observe for this purpose is the common white cabbage butterfly, that lays its eggs at random around the leaves of the cabbage-plant; though it occupies only a moment

in depositing an egg. The large orange-red butterfly (*Anosia plexippus*) acts in much the same way, laying also single eggs, generally on the under side of the leaves of milk weeds. Some butterflies lay their eggs in considerable masses. This is true of the large black butterfly (*Euvanessa antopia*), which deposits its eggs upon the twigs of elm and willow trees. It will require very careful work to note the exact process of egg-laying, and quite careful looking to find the eggs even after one sees about what part of the leaf they are laid upon. Most butterfly eggs are very beautiful objects when examined under the microscope.

Hatching.—If one succeeds in finding the eggs of butterflies it will be extremely interesting to watch the mode of hatching. Usually, the eggs hatch early in the morning, though there is considerable variation, especially if the eggs are kept in the house. Usually, there is a change of color just before hatching, and the insect begins to dig its way out on a particular side or end of the egg. Sometimes the eggshell is eaten up; at other times a hole only large enough to allow the butterfly to escape is made. The method of making the opening, the various efforts necessary in order to escape from the egg, and the treatment of the shell, all deserve attention; also the appearance of the shell after the caterpillars leave it should be noted. The time necessary for hatching will be found to differ a great deal with different species, but generally more with the same species, according to the vigor of the young worm, and the temperature.

Feeding.—Very soon after hatching, the insects begin to search for food. If the right sort is furnished, the insect will very shortly begin to eat into the surface of the leaf, and it will be possible to observe the process of feeding by means of a hand magnifier; or if examined very closely, much can be be seen with a naked eye. Points especially to be noted in the very young caterpillar are that it attacks the leaf in a very different manner from that of the larger insect, that it eats from a different portion of the leaf, and that it requires a different length of time for a meal. It will be very easy to

watch the insect, to note how long the time between meals, how it behaves itself between the feeding times, and the time occupied and amount of food taken at each feeding.

Food-Plants.—Each species of butterfly has its own peculiar food-plants, often a single species only; and it seems to be impossible to make them feed upon other plants. There are some notable exceptions to the rule of a single food-plant; one of our common butterflies, for instance, feeds almost equally often on elm and willow, two widely different plants. In most cases when the butterfly larva feeds on more than one plant, they will be very closely related to each other, belonging to the same natural family, for instance. An interesting experiment, which can be tried whenever one is fortunate enough to find a butterfly caterpillar, is to try all manner of leaves, placing them all in the same box, and noting on which the caterpillar will feed. While it will generally be found that one or two plants are all that are eaten, the list can be made larger by confining a caterpillar in a box with a single plant until it is quite hungry, when it will often eat things that it would not touch if other food was available. Food-plants of most of our common butterflies are given in the latter part of this Bulletin, but probably with experiments of this kind the list for each species might be very greatly increased. In observing the manner of eating, one might note how the insect is aided in the process by its three pairs of true legs; how the leaf fits into the mouth in just the right position for the jaws to bite off a piece; how, in feeding, the insect moves its head downward towards its breast, taking bite after bite until it reaches as far as is convenient, and then moves back near the starting point and mows off another swath; how it acts when it comes to a vein in the leaf; the difficulty it experiences in biting into it, and how sometimes, if it is very large, it gives up and leaves the vein, continuing to eat off the thinner parts of the leaf; how intent the insect is while eating, allowing one to handle it quite freely, and how, when handled too roughly, it takes considerable time before it recovers its composure

enough to begin again to feed; how much more it takes to disturb it when it is hungry, than when it is nearly through feeding.

Growth.—Caterpillars increase very rapidly in size. After a litttle acquaintance with them one can sometimes judge quite accurately of the worm by size; that is, caterpillars one, two, or three days' old are decidedly different in size. Note what part of the body increases, or whether all parts increase alike; especially notice the total length as compared with the size of the head or of the legs. Try to get some estimate of the amount of increase in size that is produced by a certain quantity of food. Note that the growth of the insect is not uniform; that some days even, just before the moulting periods, it seems to decrease rather than increase.

Moulting.—The moulting process just referred to is an extremely interesting process to watch; how the insect comes out of its old skin; where the break occurs; how the legs escape, one by one; how the legs are pulled out without disengaging the old claws that are hooked into the silken carpet spun by the worm just before moulting; and how the spines aid in the process of slipping the skin down the segments of the body. With a little care one can even notice how the breathing-tubes pull out through the breathing-holes along the side. Most insects have a particular time of day for the moulting process, and the different moults occupy different lengths of time preparatory to the casting of the skin.

Social Habits.—Most butterflies, while young, are entirely solitary in their habits. Some caterpillars, however, especially those that are produced from eggs laid in a mass, are more or less social, and in a few cases are distinctly social insects, living together throughout their whole feeding period, and only separating as they finally begin to search for a place to form their chrysalids. These social insects move about at the same time, going from one part of the plant to another always together; generally being able to touch each other and passing over the same track in

their migrations. Like other caterpillars, they spin as they go a thread of silk, which they attach to the surface, so that they make quite a distinct silken pathway by the time the whole colony has gone over part of the stem. Not only do the social insects feed together, but at each time that they shed their skin they all seem to cease to feed about the same time, and those that cast their skin first appear to wait some time even for their slower brethren, so that they all begin to feed at nearly the same time. Of course, there are a few weaker members of the family that fail to moult at the time the majority do, and after a moult or two they show very conspicuously among the others by their small size. As a rule these weakly caterpillars die before they are fully grown.

Nests.—A good many of the caterpillars of butterflies live freely exposed on the leaves of plants and make no effort at concealment, but there are quite a number of very interesting cases of nest-building. One of the most curious of nests—something which can hardly be called a nest—is where a portion of the leaf serves as a resting place, and the only nest-structure to be found upon it is a little carpet of silk to rest upon. This portion is separated from the rest of the leaf by the manner in which the leaf is eaten, and the position the insect takes is such that it is splendidly disguised. Most of the nests of butterflies are produced by sewing leaves together—sometimes it may be the leaves at the upper end of the stem, sometimes two or three leaves down the side of the stem, or again a single leaf may be bent upon itself so as to produce a neat little pocket in which the insect hides; sometimes only a portion of the leaf will be folded over—that portion generally separated from the other parts of the leaf by the caterpiller eating out a narrow strip across part of the blade. The accompanying drawing, shows one of the most peculiar forms of

FIG. 5.—Nest of hibernating larva.

nests, in which part of the leaf serves as the nest and the remainder is eaten in such a way as to aid in disguising the structure. Most of the nests of butterflies are for concealment during the summer, at the time when plants and insects are both growing; but the style last described is made for passing the winter, and it will be noticed that the leaf is sewed fast to the twig to prevent its dropping as do other leaves in the autumn. These nest structures are not generally abundant enough to enable one to find them whenever desired, but as in many things about butterflies one should keep a lookout for them while rambling over the fields. Sooner or later one will, if persistent, be rewarded by finding the object of his search.

Pupation:—When a caterpillar becomes full grown, it moults into an object possessing a very different form. This last moult requires more time than any of the previous ones, and much more elaborate preparation is made by the caterpillar before entering upon it. Instead of making the silken carpet for all of its legs to stand upon, it makes a smaller, but more perfect patch of silk for the hind legs; and generally, in addition, makes a girdle about the middle of the body, attaching it on either side, and holding the body against the surface upon which it is standing. Some butterflies do not provide this girdle, and depend only on the carpet under the last pair of legs. After this preparation the skin splits, and as the new insect begins to appear, its difference from the larva will be noticed. The pupa is without appendages capable of movement, though there really are legs and wings. These lie against the body and soon become immovably glued down. At first they can be lifted, however, and if held away from the body until dried a little, will never become attached. The most interesting point in the whole process is the means by which the insect finally gets rid of the old larval skin, for it is to be remembered that the claws of the hind feet of the larval skin are the only means of attachment. Now in some way the insect must take the end of the body out of the larval skin, reach over and get

hold of the silken carpet with the special claws found at the end of the pupa, before the larval skin becomes detached. This process is not so difficult in those forms possessing the girdle; but when the girdle is not present one must actually see the process in which this is accomplished, before he would believe it possible. There is no better insect on which to observe this than the milkweed butterfly (*Anosia plexippus*).

Emergence:—The process by which the butterfly escapes from its pupa case is full of interest. The manner of the splitting of the skin, and the various movements of the young butterfly as it forces its way out of the pupa skin, the undeveloped wings hanging down, bag-like, from the sides of the young butterfly, and their gradual enlargement until they take on the full size and shape of the true butterfly, can never lose their interest no matter how often the process is observed. The accompanying figure (6) will show the appearance of the chrysalis after the emergence of the butterfly.

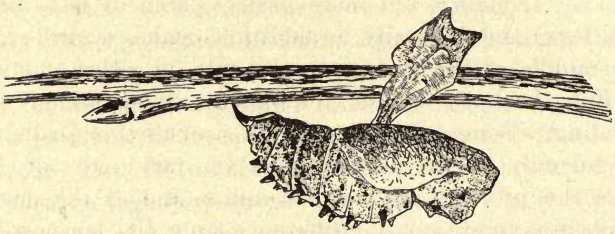

FIG. 6.—Pupal skin of Euvanessa antiopa after escape of butterfly.

Enemies:—Butterfly chrysalids are not very common, and the very unusual shape and color would doubtless fail to give to the birds the impression that it was a dainty morsel. If they were more abundant, birds might learn to recognize them and hunt for them, and then their peculiarities would fail to protect them. It appears that no one has given much attention to the insect-enemies of the pupæ of butterflies; so that about all we know about this stage is that when parasites enter the caterpillar, they usually come to their full development while the butterfly is in the

chrysalis form, and out of the chrysalis there comes the parasite instead of the butterfly.

Caterpillars or butterflies are often destroyed in great numbers by the attack of parasites. These are either flies or wasps that lay their eggs upon the caterpillar; and when this egg hatches, the little worm that is produced burrows down into the body, feeding upon the fat bodies and absorbing food also from the blood, but not generally causing the death of the caterpillar until just about the time it is ready to transform into a chrysalis, or after the chrysalis has been formed.

Various diseases often cause the death of many butterfly larvæ and pupæ; one of the commoner and more conspicuous of these is shown in Figure 7.

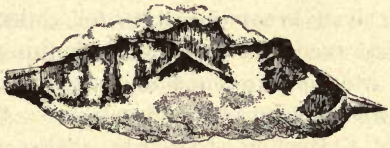

FIG. 7.—Pupa of Euvanessa antiopa that had been killed by attack of the fungus seen growing over the surface.

Many butterfly larvæ have peculiar shapes and are ornamented in various ways; all of which is supposed to have been developed as protection against birds and parasitic insects. It is a curious fact that, in many cases, the young caterpillar is quite different in appearance from the older specimen that has moulted several times; and it is thought that this difference is a protection against different enemies that are likely to attack the caterpillar at different stages in its life. The egg, even, is not without its enemies, for there are parasites that attack the egg and prevent the hatching. These parasites go through their whole development within the egg-shell, and are of course, excessively minute. Eggs of butterflies, aside from the attack of these parasites, are generally quite free from danger of insect enemies.

COLLECTING.

The making of a collection is one of the best ways of developing an interest in a subject and of recording one's observations. The method of making the collection, and the character of the collection itself, will depend upon the lines of observation that are receiving greatest attention. The commonest collections consist merely of a set of specimens of the adults, when the chief interest centers on the variety and grouping of the insects. When the interest has grown to a study of the whole life-history of an insect, the collection is made to contain not only the adult insect, but all stages of its development; and, as the interest grows wider, specimens representing all phases of the insect's activity become objects for collection. It is a good policy, however, at least when beginning a collection, to pay most attention to some one class of views, rather than to extend it equally in all directions. A collection of adult forms of butterflies, therefore, makes a very useful beginning; or one may be made to indicate sleeping habits, or feeding habits of these insects; or one representing the varying daily or seasonal peculiarities will be valuable. The following hints are given to suggest a method of procedure in making a collection.

Collection of Butterflies.—The apparatus necessary for collecting butterflies consists of: first, a means of capture; and second, a means of killing.

Capturing can be done by hand, but always with some danger to the specimens, or with loss of time; so that a net is practically necessary. Nets can be very easily made by attaching a wire hoop to the end of a stick or bamboo about the size of a broom handle, and sewing to the hoop a bag of mosquito net. A hoop about a foot in diameter will be most convenient, and the mosquito bag should be about two feet deep, or a little more. With a little practice one can become very skilful in the handling of the net, and may catch butterflies very rapidly and certainly. In approaching an

insect it is well to wait until it has alighted, and to bring the net close to it as slowly as possible, and keep it near the ground and so out of sight. When one has brought it very close so as to be sure of his prey, a sudden quick stroke, followed by a quick back movement, will securely bag the butterfly and fold the net over so that it cannot escape. It is well to make it a rule never to touch the wings with the fingers in removing the insect from the bag. A good plan is to push the wide-mouthed bottle, used for killing, into the folded net until it reaches the butterfly, when the insect will flutter into the bottle, and the insertion of the cork will hold it a prisoner.

The Killing-Bottle.—The most convenient method of killing butterflies is the use of the wide-mouthed bottle into which the butterfly can pass without injury to the wings. A bottle is better than a box because the insect can be seen within and the cork closes it tightly, thus permitting the full strength of the killing substance to act. Cyanide of potassium makes a very good poison, and can be imbedded in plaster of paris in the bottle and so be perfectly safe. Another method is to place the poison in saw-dust, or to wrap it in paper; in both cases covering it with a stiff cardboard or pasteboard fastened to the bottle by means of shellac. Another method of making a killing-bottle is to place in the bottom a small quantity of cotton which is wetted from time to time with chloroform, ether, benzine, or even common gasoline, for the vapors from all of these substances are very efficient in killing insects. A butterfly should be allowed to remain in the killing-bottle for some time after it is apparently dead, because at first the poison merely puts the insect to sleep, and it is very apt to revive if not kept in long enough.

Pinning and Setting.—After the insects are captured and killed, they are ready to be pinned and set. For pinning always use insect pins, which are much longer and have slenderer points than common pins, and are not so apt to corrode. They cost about ten or fifteen cents a hundred. A butterfly should be pinned through the middle of the

thorax, and in such a way that the body is at right angles to the pin; and the pin should be thrust through the insect far enough that twice as much pin appears below than above the body.

After the insect is properly pinned it is ready for setting. For this purpose a setting-board is necessary. There are two styles of these; in one a groove is made large enough to receive the body of the insect, and in the bottom of the groove an awl-hole is made, through which the point of the pin is thrust; the wings are then spread and pinned down to the board in such a way as to show the most possible of their surface. The fore-wings should be pulled forward so far that their hind edges may lie in the same straight line, and the hind wings brought to such a position as to leave about the same gap next to the body as to the front wings. In pulling these wings forward a pin may be used, inserting it just behind the strong vein and thus avoiding danger of tearing. After the wings are pinned down in the proper position it is a good plan to lay strips of paper over them to hold them straight; and it is possible, after these paper strips are pinned down, to remove the pins that go through the wings: the holes they have made will then be scarcely noticeable; whereas, if the pins are left in the wings until they are dry, the holes will always be easily seen.

The other style of setting-board is a plain, flat board with a larger awl hole, big enough to take the head of a pin. The insect in this case is laid on the board back down, the head of the pin projecting into the awl-hole; the rest of the process is the same as described above.

The insects should be allowed to remain on the setting-board until they are thoroughly dry, and this sometimes may take a week or two. After the insects are thoroughly dry, the paper strips are removed and the specimen is ready to be placed in the collection. It is a good plan to write on a small piece of paper the date and locality of every specimen, and to pin this below it.

Breeding of Butterflies.—The care of living insects is known among naturalists as insect-breeding, and serves

both for the study of the transformations and for the securing of perfect specimens for the collection. The most difficult part of the process is obtaining the eggs; occasionally one will find them in the field, but ordinarily they will have to be obtained by enclosing the butterflies in a sleeve-like bag of cheese-cloth upon their food-plant. If the butterfly happens to be in just the right condition, eggs will be obtained; otherwise, not, so that many attempts must often be made before success is reached. After the eggs are obtained the rest of the process is much simpler. No attention need be given to the eggs until the young caterpillars are hatched, or are about to hatch, when they should be taken indoors and provided from time to time with their proper food. It is generally well to keep them enclosed, so that they will not escape. For a few caterpillars use a lamp chimney or lantern globe set upon a flower-pot, within which a twig of the food is inserted in moist sand; over the top may be tied a piece of cheese-cloth to prevent the escape of the worms. In this way the food may be kept fresh for several days. It is a good thing to keep the breeding cage clean by removing all droppings, or better still, to make a new cage at each change of food. It is well also to have as few larvæ as convenient in each cage. After the larvæ are full grown and have pupated, the pupæ should be kept in a dry situation, but occasionally sprinkled with water, so that they will not dry out too much until they are ready to hatch. It is well to keep each by itself in a pasteboard box of sufficient size to enable the butterfly, as it emerges, to have ample room for spreading its wings; but they must be looked after very regularly, so as to remove them as soon as the wings are firm. It takes about two days after emergence before the wings have obtained their full hardness and the insects are ready to be killed and spread for the collection.

LIST OF THE BUTTERFLIES OF CALIFORNIA.

The classification or naming of insects is of but little value in itself; but as a means of recording accurately

one's observations on the development of group forms, or of such observations as are suggested in this Bulletin, it becomes of the highest importance. The following list and the illustrations accompanying it, are designed to aid the student in at least approximately placing his specimens. The two plates of photographs give pictures of forty of the commoner species, so that most of the kinds likely to be observed by the students can be immediately located. At the beginning of each family are also given sketches showing the venation of the wings of most of the genera, and to these reference is made by the numbers outside of parentheses. In doubtful cases these will be found useful. The list proper (numbered consecutively *within* parentheses) contains the names of all the butterflies found in the State; so as surely to include all that occur here, those recorded from adjoining States are also given, but in every case that fact is noted. Thus, the word "Arizona," following a species name, indicates that the species has not yet been recorded from California, but might be looked for along the south-eastern border of the State. Notes as to abundance, food habits, and distribution, follow the more important species.

FAMILY NYMPHALIDÆ.

This family is characterized by the functionless front legs, (see Fig. 2) and is considered the highest-developed of the series. The species are mostly of large size and vary greatly in appearance.

Sub-family EUPLOEINAE.

Anosia. 1. (1) A. plexippus, Linn. (Plate 1). Occurs all over the State; flies all the year; larva feeds on milkweed. Perhaps the most useful butterfly for study. (2) A. berenice Cram., Arizona and southern California. (3) A. strigosa, Bates, Arizona.

Sub-family ITHOMIINAE.

Mechanitis. 2. (4) M. californica, Reak., (5) M. utemasia, Reak.
Dynothea. 3. (6) D. lycaste, Fabr. The species of this family are all rare and confined to the southern part of the State.

Sub-family NYMPHALINAE.

Agraulis. 4. (7) A. vanillæ, Linn. (Plate 1). Very abundant in the south. Larva feeds on passion vine.

Euptoieta. 5. (8) E. claudia, Cram. (9) E. hegesia, Cram. Two rarer passion-vine butterflies, also belonging to the south.

Argynnis 6. (10) A. nokomis, Edw. (Plate 1.) This species and the two following are yellowish instead of reddish-brown in the female, as is the rule in the genus. The female is figured. (11) A. nitocris, Edw., Arizona, Nevada. (12) A. leto, Behr. A common form in the Yosemite valley. (13) A. cybele, Fabr., Arizona. (14) A. aphrodite, Fabr., Arizona. (15) A. cipris, Edw., (16) A. nausicaä,

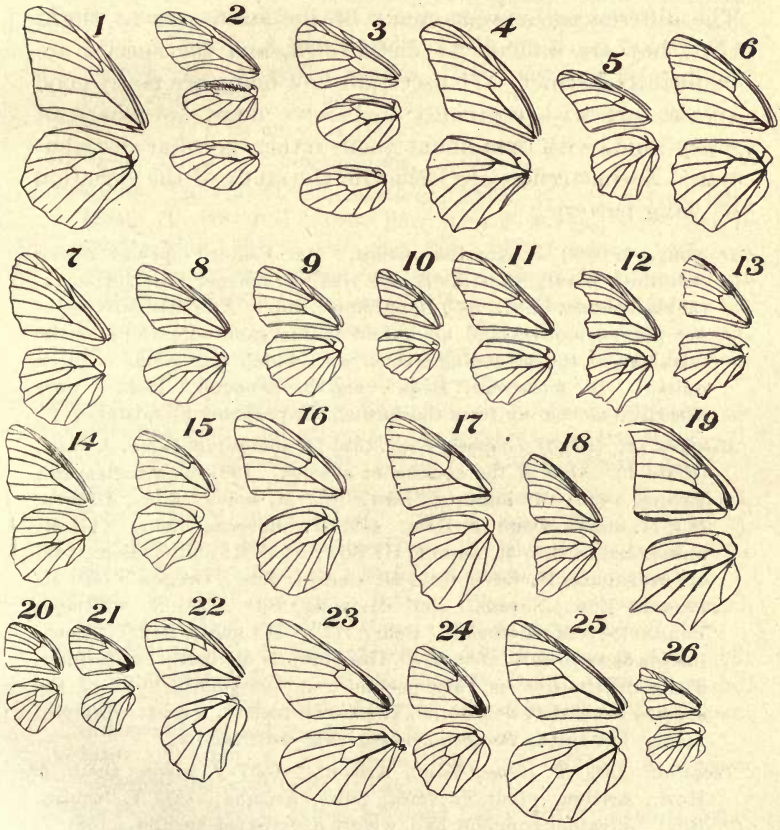

Plate 3.

Edw., Arizona. (17) A. hippolyta, Edw., (18) A. bremneri, Edw. These last two are rather northern forms. (19) A. zerene, Bdv. (20) A. monticola, Behr. These last two are common in the Yosemite region and of rather wide distribution elsewhere. (21) A. behrensi, Edw. Another northern form. (22) A. halcyone, Edw., Arizona. (23) A. oweni, Edw., (24) A. chitone, Edw., (25) A. semiramis, Edw., (26) A. coronis, Behr. (27) A. callippe, Bdv. (28) A. nevadensis, Edw., (29) A. edwardsi, Edw., (30) A. liliana, H. Edw., (31) A. montivaga, Behr. (32) A. egleis, Bdv.

The above rather formidable list is made up mostly of somewhat rare butterflies. The species of this genus are almost exclusively confined to the eastern edge of the State. The differences between many of the forms are so slight that they are difficult to distinguish, and the species are doubtfully distinct. To ascertain how many are really good species, we wish especially to receive many specimens of every kind, with data about their rather peculiar distribution. No butterflies are better for the study of the variation of wing pattern.

Brenthis. 7. (33) B. myrina, Cram. An Eastern species rather doubtfully credited to this State. (34) B. helena, Edw., Arizona. (35) B. bellona, Fabr., (36) B. epithore., Bdv. The last two species are not uncommon and are found in the same situations as the members of the preceding genus, with which this genus is often united. B. morrisoni, Reak., and B. nenoquis, Reak., were described as coming from California, but probably by mistake.

Melitaea. 8. (37) M. cooperi, Behr. (38) M. chalcedon, Doub. & Hew. (Plate 1). One of the commoner species. (39) M. macglashani, Rivers. (40) M. augusta, Edw. (41) M. colon, Edw., Oregon. (42) M. anicia, Doub. & Hew. (43) M. nubigena, Behr. (44) M. quino, Behr. (45) M. baroni, H. Edw. (46) M. editha, Behr. (47) M. rubicunda, H. Edw. (48) M. sterope, Edw., Oregon. (49) M. acastus, Edw., Nevada. (50) M. palla, Bdv. (51) M. whitneyi, Behr. (52) M. hoffmani, Behr., (53) M. gabi, Behr. These insects deserve careful study. The group is distinctly Californian. Their distribution is very peculiar, and the distinctness of the species somewhat doubtful. The larvæ feed on a great variety of plants, but chiefly *Scrophulariaceae* (Fig-wort family).

Thesalia. (54) T. perse, Edw., Arizona. (55) T. elada, Doub. & Hew., Arizona. (56) T. chara, Edw., Arizona. (57) T. leanira, Bdv. A rather common and widely distributed species. (58) T. alma, Strk., Arizona. (59) T. wrighti, Edw. (60) T. thekla,

Edw. (61) T. bolli, Edw., Arizona. (62) T. minuta, Edw., Arizona. (63) T. arachne, Edw., Arizona. (64) T. nympha, Edw., Arizona.

The above group is generally united with the preceding genus, but seems to be a distinct group. Many of the species are doubtfully distinct. Nothing is known of the food habits.

Charidryas. (65) C. nyeteis, Doub. and Hew. Widely distributed; larva feeds on Compositæ (Composite family). (66) C. carlota, Reak. This genus is generally associated with the next.

Phyciodes. 9. (67) P. tharos, Dru. Widely distributed, larva feeds on Actinomeris and probably Compositæ generally. (68) P. pratensis, Behr. (Plate 1). A common species (69) P. orseis, Edw. (70) P. mylitta, Edw. A common species. (71) P. montana, Behr. (72) P. picta, Edw. (73) P. hermas, Hew.

Eresia. 10. (74) E. punctata, Edw.

Chlosyne. 11. (75) C. crocale, Edw.

Polygonia. 12. (76) P. interrogationis, Fabr. (77) P. satyrus, Edw. (Plate 1). (78) P. rusticus, Edw. (79) P. faunus, Edw. (80) P. sylvius, Edw. (81) P. zephyrus, Edw. (82) P. silenus, Edw. A group of very characteristically marked insects; very uniform in pattern and habits. The larvæ feed on nettles and allied plants.

Euvanessa. 13. (83) E. antiopa, Linn. (Plate 1). A very common butterfly, and one of the most available for breeding, since the larvæ are social, feeding on elm and willow.

Eugonia. (84) E. californica, Bdv. (Plate 1). Closely allied to the preceding genus, but with much the appearance of Polygonia.

Aglais. (85) A. milberti, Godt. (Plate 1). Allied to Euvanessa.

Vanessa. 14. (86) V. atlanta, Linn. (Plate 1). (87) V. huntera, Fabr. (88) V. cardui, Linn. (89) V. caryæ, Hubn. (Fig. 3). This species is the commoner form, like the other species of the genus; the larva feeds on a variety of plants, including nettles.

Junonia. 15. (90) J. cœnia, Hubn. (Plate 1). A very common species. (91) J. genoveva, Cram. (92) J. lavinia, Gram.

Basilarchia. 16. (93) B. astyanax, Fabr. (94) B. arthemis, Dru. (95) B. weidemeyeri, Edw. (96) B. disippus, Godt. (97) B. lorquini, Bdv. (98) B. hulsti, Edw., Arizona. These insects feed on a great variety of trees and shrubs.

Adelpha. 17. (99) A. californica, Butl. (Plate 1). A common butterfly; the larva feeds on oak.

Chlorippe. 18. (100) C. celtis, Bdv. and Lec. (101) C. antonia, Edw. (102) C. leilia, Edw. None of these insects are common.

Pyrrhanæa. 19. (103) P. morrisoni, Edw., Arizona.

Sub-family SATYRINAE.

Neonympha. 20. (104) N. henshawi, Edw. (105) N. rubricata, Edw.

Cœnonympha. 21. (106) C. california, Westw. (Plate 1). Very common towards fall. (107) C. inornata, Edw. (108) C. pamphiloides, Reak.

Gyrocheilus. 22. (109) G. tritonia, Edw., Arizona.

Neominois. 23. (110) N. ridingsi, Edw.

Cereyonis. 24. (111) C. wheeleri, Edw. (112) C. meadi, Edw. (113) C. sthenele, Bdv. (114) C. baroni, Edw. (115) C. silvestris, Edw. (116) C. œtus, Bdv.

Œneis. 25. (117) O. nevadensis, Feld. (118) O. californica, Bdv. (119) O. iduna, Edw. (120) F. chryxus, Westw. (121) O. ivallda, Mead.

Sub-family LIBYTHEINAE.

Libythea. 26. (122) L. bachmanii, Kirtl. (123) L. carinenta, Cram.

FAMILY LYCAENIDÆ.

This family consists entirely of small delicate butterflies, usually of a blue or copper color. They can be distinguished by the narrowness of the face between the eyes.

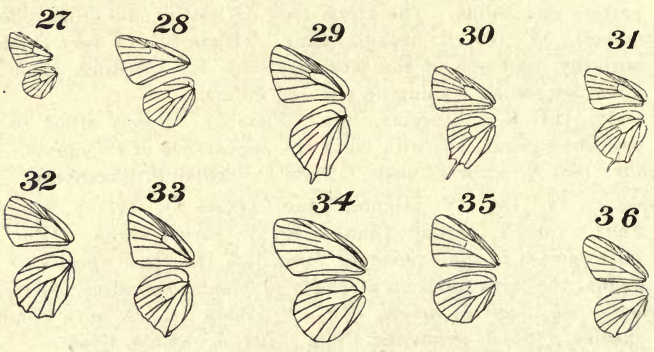

Plate 4.

Sub-family ERYCININÆ.

Chrysobia. 27. (124) C. mormo, Feld. (125) C. cythera, Edw., Arizona. (126) C. virgulti, Behr. (Plate 1). (127) C. nais, Edw. Arizona, (128) C. palmeri, Edw., Arizona. (129) C. zela, Butl., Arizona.

Calephelis. 28. (130) C. nemesis, Edw. (131) C. australis, Edw. The insects of this sub-family all belong to the south. In most cases the larva is unknown.

Sub-family LYCÆNINÆ.

Tribe *Thecline*. The "Hair streaks."

Habrodius. (132) H. grunus, Bdv.

Atlides. (133) A. halesus, Cram. These two genera are generally united with the following with which they are closely allied. The larvæ feed upon oak.

Thecla. 29. (134) T. sylvinus, Bdv. (135) T. itys, Edw., Arizona. (136) T. auretorum, Bdv. (137) T. dryope, Edw. (138) T. spadix, H. Edw. (139) T. tetra, Behr. (140) T. chalcis, Behr. (141) T. sæpium, Bdv. (142) T. nelsoni, Bdv. (143) T. adenostomatis, H. Edw. (144) T. tacita, H. Edw. (145) T. spinetorum, Bdv. (146) T. blenina, Hew. The early stages of all our species are unknown.

Uranotes. 30. (147) U. melinus, Hubn. (Plate 1). This is one of the hop butterflies and very widely distributed. (148) U. alcestis, Edw., Arizona.

Metura. 31. (149) M. acis, Edw. (150) M. leda, Edw., Arizona, (151) M. ines, Edw., Arizona. The early stages of these species are unknown.

Callypsyche. (152) C. behri, Edw. A northern species whose life history is unknown.

Incisalia. 32. (153) I. augusta, Kirby. (154) I. iroides, Bdv. (155) I. fotis, Strk., Arizona. (156) I. eryphon, Bdv. The life history of none of these is known.

Callophrys, (157) C. dumetorum, Bdv. (158) C. apama, Edw.

Erora. (159) E. læta, Edw., Arizona.

Strymon. 33. (160) S. titus, Fabr., Arizona. Larva feeds on wild cherry and plum.

Tribe *Chrysophanini*. The "Coppers."

Tharsalea. (161) T. arota, Bdv. The larva feeds on wild gooseberry. (162) T. virginiensis, Edw. (163) T. hermes, Edw.

Gœides. 34. (164) G. xanthoides, Bdv. (Plate 1). (165) G. editha, Mead, Nevada. (166) G. gorgon, Bdv. The larvæ of these are unknown.

Epidemia. (167) E. mariposa, Reak. (168) E. zeroe, Bdv. (169) E. helloides, Bdv. The larvæ of these are also unknown.

Helodes. (170) H. hypophlæas, Bdv. (Plate 1).

Tribe *Lycaenini* The "Blues."

Satrium. (171) S. fuliginosum, Edw.

Cupido. (172) C. heteronea, Bdv. (173) C. clara, H. Edw. (174) C. lycea, Edw., Arizona. (175) C. fulla, Edw. (176) C. sæpiolus, Bdv. (177) C. dædalus, Behr. (178) C. icarioides, Bdv. (179) C. pheres. Bdv. (180) C. phileros, Bdv. (181) C. ardea, Edw.

Nomiades. (182) N. xerxes, Bdv. (183) N. antiacis, Bdv. (184) N. lygdamas, Doub.

Phaddrotes. (185) P. sagittigera, Feld.

Philotes. (186) P. speciosa, Edw. (187) P. sonorensis, Feld.

Agriades. (188) A. podarce, Feld.

Rusticus. (189) R. enoptes, Bdv. (190) R. glaucon, Edw., Nevada. (191) R. battoides, Behr. (192) R. shasta, Edw. (193) R. melissa, Edw., Nevada, Arizona. (194) R. scudderi, Edw. Larva feeds on lupines. (195) R. lotus, Lint. (196) R. acmon, Edw. (197) R. anna, Edw. (Plate 1).

Cyaniris. 35. (198) C. pseudargiolus, Bdv. & Lec. Larvæ feed on a great variety of plants.

Everes. 36. (199) E. tejua, Reak. (200) E. amyntula, Bdv. (201) E. comyntas, Gdt., Arizona. Larva feeds on leguminous plants. (202) E. monica, Reak.

Hemiargus. (203) H. isola, Reak. (204) H. gyas, Edw., Arizona.

Brephidium. (205) B. exile, Bdv. (Plate 1).

Leptotes. (206) L. marina, Reak.

The life history of these insects, except in the few cases noted above, is still known.

FAMILY PAPILIONIDÆ.

This family includes two distinct types of butterflies, representing the two sub-families.

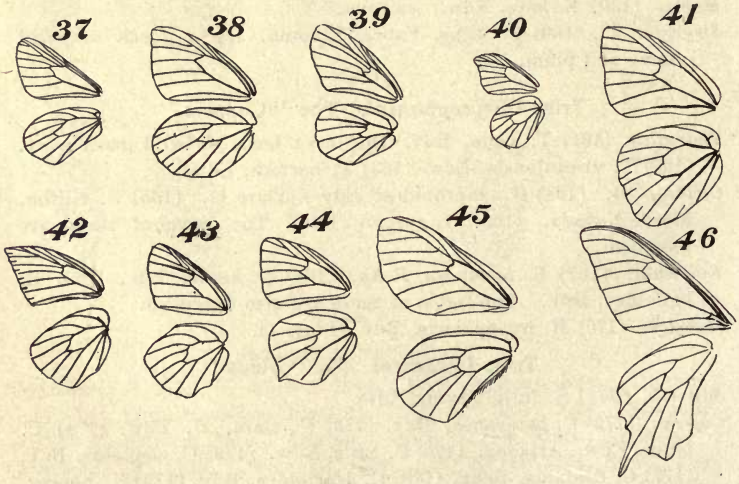

Plate 5.

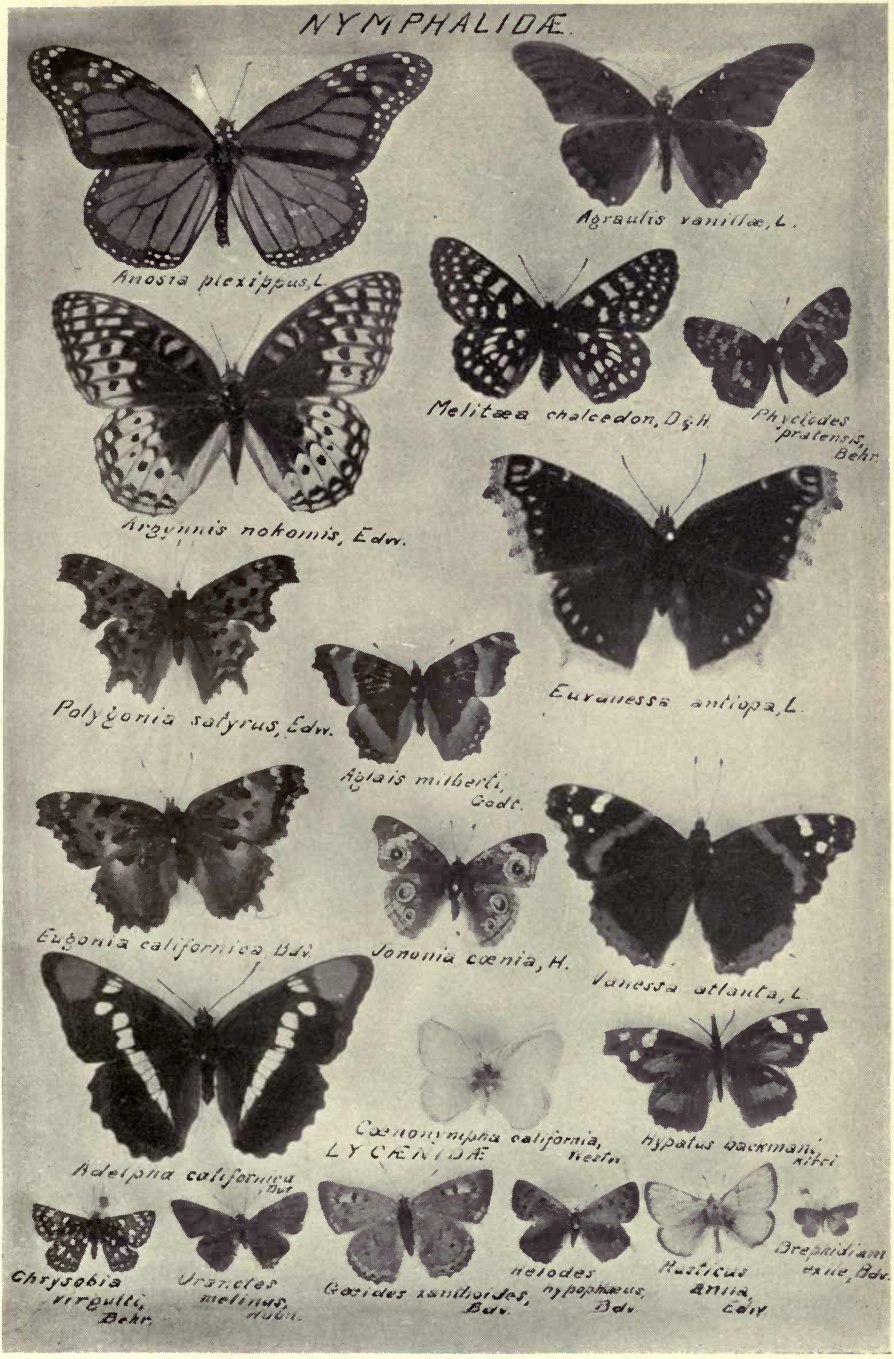
NYMPHALIDÆ.
Anosia plexippus, L.
Agraulis vanillæ, L.
Melitæa chalcedon, D. & H.
Phyciodes pratensis, Behr.
Argynnis nokomis, Edw.
Polygonia satyrus, Edw.
Aglais milberti, Godt.
Euvanessa antiopa, L.
Eugonia californica Bdv.
Junonia cœnia, H.
Vanessa atlanta, L.
Adelpha californica Bdv.
Cœnonympha california, Westw.
LYCÆNIDÆ
Hypatus bachmani, Kirby
Chrysobia virgulti, Behr.
Urandes melinus, Hübn.
Gazides xanthoides, Bdv.
Melodes nyphaeus, Bdv.
Rusticus Attila, Edw.
Brephidium exile, Bdv.

PLATE 1.

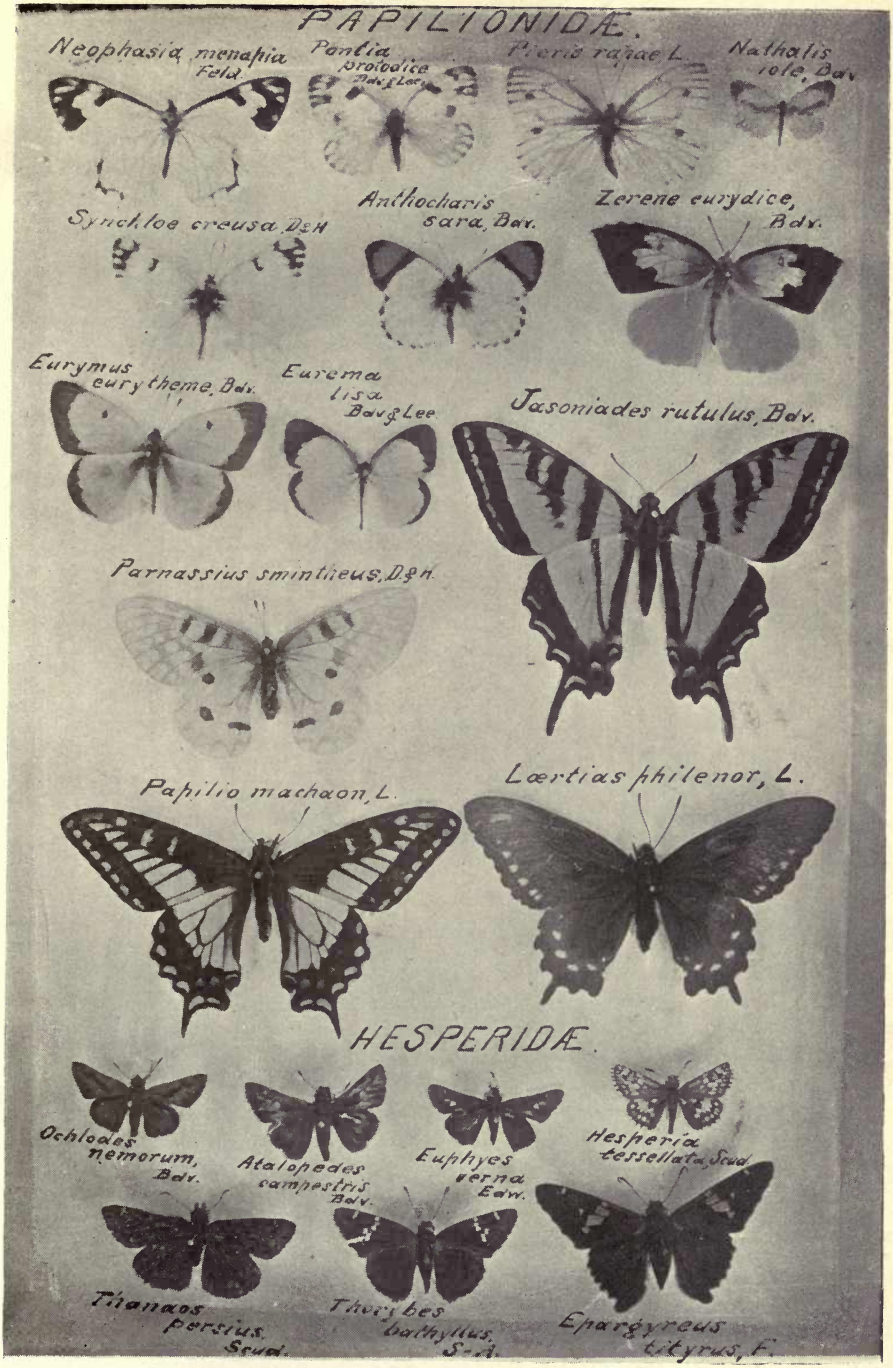
PAPILIONIDÆ.
Neophasia menapia Feld.
Pontia protodice Bdv. & Lec.
Pieris rapae L.
Nathalis iole, Bdv.
Synchloe creusa, D. & H.
Anthocharis sara, Bdv.
Zerene eurydice, Bdv.
Eurymus eurytheme, Bdv.
Eurema lisa Bdv. & Lec.
Jasoniades rutulus, Bdv.
Parnassius smintheus, D. & H.
Papilio machaon, L.
Lærtias philenor, L.
HESPERIDÆ.
Ochlodes nemorum, Bdv.
Atalopedes campestris, Bdv.
Euphyes verna, Edw.
Hesperia tessellata, Scud.
Thanaos persius, Scud.
Thorybes bathyllus, S.-A.
Epargyreus tityrus, F.

PLATE 2.

Sub-family PIERINÆ.

Tribe *Pierini*. The "Whites."

Neophasia. 37. (207) N. menapia, Feld. (Plate 2). This is a northern species; the larva feeds on pine and fir.

Pontia. (208) P. beckeri, Edw. (209) P. sisymbri, Bdv. (210) P. occidentalis, Reak. (211) P. protodice, Bdv. and Lec. (Plate 2). The last species is very abundant; the larva feeds on cabbage and other Cruciferæ (mustard family), as do the other species of the genus. This genus is generally united with the Pieris.

Pieris. 38. (212) P. napi, Esp. Larva feeds on mustard. (213) P. rapæ, Linn. (Plate 2). The commonest and most injurious insect of the family and perhaps of all butterflies. The larva feeds on cabbage. Is a very useful insect for study.

Nathalis. 39. (214) N. iole, Bdv. (Plate 2). This insect is found in the southern part of the State.

Midea. (215) M. lanceolata, Bdv. The larva feeds on Turritis.

Synchloë. (216) S. creusa, Doub. & Hew. (Plate 2). (217) S. ausonides, Edw. These feed on Cruciferæ (mustard family).

Anthocharis. 40. (218) A. latta. (219) A. sara, Bdv. (Plate 2). (220) A. cethura, Field. (221) A. pima, Edw., Arizona. These feed, as far as known, on Cruciferæ (mustard family). The three preceding genera are sometimes grouped as one, either under the name Anthocharis or Euchloë.

Tribe *Coliini*. The "Yellows."

Callidryas. 41. (222) C. eubule, Linn. (223) C. philea, Linn., Arizona. The larvæ of these feed on leguminous plants.

Zerene. 42. (224) Z. eurydice, Bdv. (Plate 2). The larva feeds on Amorpha californica (Californian false indigo). (225) Z. cæsonia, Stoll.

Eurymus. 43. (226) E. eurytheme, Bdv. (227) E. philodice, Gdt. (228) E. harfordi, H. Edw. (229) E. occidentalis, Scud. (230) E. christiana, Edw., Oregon. (231) F. alexandra, Edw., Nevada, Oregon. (232) E. emilia, Edw. (233) E. interior, Scud. (234) E. behri, Edw. These insects vary greatly, and the differences between the species are so small that it seems doubtful that they are really distinct. The larvæ feed on a variety of plants of the Leguminosæ (pulse family), especially clover and alfalfa.

Xanthidia. 44. (235) X. gundlachia, Poey, Arizona. (236) X. proterpia, Fabr., Arizona. (237) X. nicippe, Cram., Arizona. Larva feeds on Cassia. (238) X. mexicana, Bdv. (239) X. damaris, Feld., Arizona. Southern forms. This and the next genus are generally united under the name Terias.

Eurema. (240) E. lisa, Bdv. & Lec. The larva feeds on Cassia.

Sub-family PAPILIONINÆ.

Tribe *Parnassiini*. The "Parnassians."

Parnassius. 45. (241) P. nomion, Fisch. (242) P. clodius, Men (243) P. smintheus, Db. & Hew. (Plate 2). The larvæ of these delicate southern butterflies feed on Sedum (stone crop) and Saxifrage.

Tribe *Papilionini*. The "Swallow-tails."

Jasoniades. (244) J. eurymedon, Bdv. The larva feeds on Rhamnus and various other plants. (245) J. rutulus, Bdv. (Plate 2). The larva of this common species feeds on alder and willow. (246) J. daunus, Bdv. The larva feeds on various species of the rose family. (247) J. pilumnus, Bdv. The larva feeds on laurel.

Papilio. 46. (248) P. asterias, Fabr. (249) P. bairdi, Edw., Arizona. (250) P. indra, Reak. (251) P. pergamus, H. Edw. (252) P. hollandi, Edw., Arizona. (253) P. machaon, Linn. (254) P. oregonia, Edw., Oregon, Arizona. (255) P. zolicaon, Bdv. (256) P. americus, Koll. These all feed as larvæ on various Umbelliferæ (parsley family). There is much room for doubt whether all the species are distinct, but there are three quite distinct groups containing respectively two, three, and four of this species.

Euphloedes. (257) E. troilus, Linn. Very doubtfully credited to this State. The larva feeds on spicewood and sassafras.

Laertias. (258) L. philenor, Linn. (259) L. mylotes, Bates. The larva feeds on Aristolochia (Dutchman's pipe).

Heriaclides. (260) H. thoas, Linn., Arizona. The larva feeds on citrus trees.

FAMILY HESPERIDÆ.

This family of heavy bodied butterflies known as "skippers" can be distinguished by their very wide heads and the insertion of the antennæ far apart. They are considered the lowest family, and the one that approaches nearest to the moths.

These insects need more study along every line. The generic placing of some of the species given below is rather doubtful.

Sub-family PYRRHOPYGINÆ.

Pyrrhopyge. 47. (261) P. araxis, Hew., Arizona.

Sub-family HESPERIINÆ.

Eudamus. 48. (262) F. simplicius, Stall. (263) F. albofasciatus, Hew.

Plestia. 49. (264) P. dorus, Edw., Arizona.

Epargyreus. 50. (265) F. tityrus, Fabr. (Plate 2). The larva lives in a nest and feeds on various leguminous plants.

Thorybes. 51. (266) T. pylades, Scud. The larva feeds on Lespedeza (bush clover) and Desmodium (tick trefoil). (267) T. nevadæ, Scud., Nevada. (268) T. bathyllus, Sm. & Abb. (Plate 2). Larva feeds on a variety of leguminous plants. (269) T. moschus, Edw., Arizona. (270) T. hippalus, Edw., Arizona. (271) T. drusius, Edw., Arizona. (272) T. epigena, Edw., Arizona.

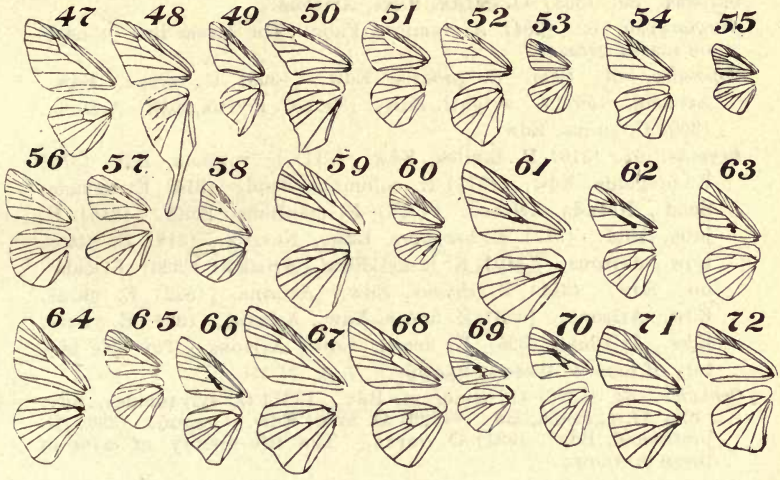

Plate 6.

Achalarus. 52. (273) A. cellus, Bdv. & Lec. The larva feeds on Desmodium (tick-trefoil).

Hesperia. 53. (274) H. ericetorum, Bdv. (275) H. oceanus, Edw., Arizona. (276) H. domicella, Erich, Arizona. (277) H. tessellata, Scud. Very common. (278) H. cæspitalis, Bdv. (279) H. scriptura, Bdv. The larvæ of all these are supposed to feed on various Malvaceæ (mallow family).

Systasea. 54. (280) S. zampa, Edw., Arizona.

Pholisora. 55. (281) P. catullus, Fabr. The larvæ feed on Chenapodium. (282) P. pirus, Edw., Arizona. (283) P. ceos, Edw., Arizona. (284) P. libya, Scud.

Thanaos. 56. (285) T. brizo, Bdv. & Lec. (286) T. icelus, Lint. The larvæ of these two feed on oaks. (287) T. persius, Scud. (Plate 2). The larva feeds on willow. (288) T. afranius, Lint., Arizona. (289) T. juvenalis, Fabr., Arizona. The larva feeds on oak and also on leguminous plants. (290) T. propertius, Lint. (291) T. pacuvius, Lint., Arizona. (292) T. tatius, Edw.,

Arizona. (293) T. clitus, Edw., Arizona. (294) T. funeralis, Lint. (295) T. tristis, Bdv. (296) T. tibullus, Scud-Burg.

Sub-family PAMPHILINÆ.

Amblyscirtes. 57. (297) A. ænus, Edw. (298) A. simius, Edw. (299) A. cassus, Edw. (300) A. nanno, Edw. These four species are Arizonian, and nothing is known of their life histories.

Pamphilia. 58. (301) P. mandan, Edw. (302) P. omaha, Edw. The larvæ of these feed on grasses.

Oarisma. 59. (303) O. garita, Reak, Arizona.

Ancyloxypha. 60. (304) A. numitor, Fabr. The larvæ live in nests on marsh grasses.

Copæodes. 61. (305) C. procris, Edw. (306) C. arene, Edw., Arizona. (307) C. wrighti, Edw. (308) C. myrtis, Edw., Arizona. (309) C. eunus, Edw.

Erynnis. 62. (310) E. taxiles, Edw. (311) E. ruricola, Bdv. (312) E. oregonia, Edw. (313) E. columbia, Scud. (314) E. nevada, Scud., Nevada, Arizona. (315) E. manitoba, Scud. (316) E. juba, Scud. (317) E. harpalus, Edw., Nevada. (318) E. ottoë, Edw., Arizona. (319) E. lasus, Edw., Arizona. (320) E. cabelus, Edw. (321) E. rhusus, Edw., Arizona. (322) E. carus, Edw., Arizona. (323) E. uncas, Edw., Arizona. (324) E. yuma, Edw., Arizona. (325) E. snowi, Edw., Arizona. The life-history of none of these is known.

Ochlodes. 63. (326) O. nemorum, Bdv. (327) O. sylvanoides, Bdv. (328) O. agricola, Bdv. (329) O. milo, Edw., Oregon. (330) O. pratincola, Bdv. (331) O. verus. The life-history of none of these is known.

Atalopedes. 64. (332) A. campestris, Bdv. (Plate 2). A very common species.

Polites. 65. (333) P. sabuleti, Edw. (334) P. mardon, Edw., Oregon.

Hylephila. 66. (335) H. phylæus, Drury. (336) S. chusca, Edw. Arizona. The larvæ feed on grass.

Calpodes. 67. (337) C. pittacus, Edw. (338) C. python, Edw. (339) C. cestus, Edw. All Arizonian.

Lerodea. 68. (340) L. comus, Edw. (341) L. arabus, Edw., Arizona. (342) L. nereus, Edw., Arizona.

Limochores. 69 (343) L. cernes, Edw. (344) L. manataaqua, Scud. The larvæ live in tube-like nests on grass.

Euphyes. 70. (345) E. verna, Edw. (Plate 2). Larvæ feed on grass. (346) E. vestris, Bdv. (347) E. metacomet, Harr., Nevada. (348) E. bella, Edw., Arizona.

Oligoria. 71. (349) O. deva, Edw., Arizona. (350) O. lunus, Edw., Arizona.

Atrytone. 72. (351) A. melane, Edw. (352) A. taxiles, Edw., Nevada, Arizona.

Megathymus. (353) M. yuccæ, Bdv. & Lec., Arizona. (354) M. neumœgenii, Edw., Arizona.

THE LIVING PLANT.

By W. J. V. Osterhout,
Instructor in Botany.

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THE STUDY OF THE LIVING PLANT.

It seems to be generally admitted that plants are especially suitable objects for nature study, but it is to be regretted that too often the attention is centered on the dead plant to the exclusion of the living one. This is a mistake, and will be recognized as such if the aims of nature study are not lost sight of. These are, first, to put the child in the right attitude, to awaken his sympathetic interest in plant-life; and, second, to develop his observing and reasoning powers in leading him to find out for himself what the plant is doing and why it does it. Both these objects may be admirably attained by experiments performed by the children themselves, on living plants.

Experiments should not be performed in a haphazard manner, nor—as usually happens—to demonstrate something the child has already accepted as a fact; but to answer questions which have been previously put by the child himself, or by the teacher. I believe this point to be of fundamental importance, although generally overlooked. Experiments seem to be usually regarded as useful for demonstrative purposes only. I do not believe that for nature study at least, this is the best use to which they can be put. The child can use experiments for the same purpose as the investigator uses them, *i.e.*, for putting questions to nature, and will find in this a mental

quickening and zest such as comes in no other way. Children are investigators, in their own way, and enjoy experiments of all kinds, especially experiments with things which are alive.

An enthusiastic and sympathetic teacher will easily get the children to ask questions; the next step is to show them how to answer their own questions by experiments, or, better still, lead them to suggest for themselves how to do this. Herein lies the value of the method. It leads the child to think; reveals to him his own power to find out things, and creates an interest which does not die when he leaves the schoolroom. He gains, almost without conscious effort, an insight into plant-life which makes plants attractive and interesting wherever he sees them, and which will surely entice him into the fields. He comes to see the plant in a new and wonderfully inspiring way, as a living, struggling being, attacking its competitors, warding off its foes, adapting itself by clever devices to harsh and unfavorable surroundings; in short, solving the thousand and-one problems of its existence with consummate skill. And what he before passed over with apathy he will learn to observe, admire, and study; in some measure he will come to see the beauty and learn the lessons of common things.

Many teachers may approve of experiments, but shrink from what they suppose requires too much time and the use of complicated apparatus. I wish to point out that the most interesting and instructive experiments can be performed either with no apparatus at all or with such as the children can easily make for themselves; and that the outlay of time and money are exceedingly small, while the returns are of great and lasting value.

The experiments here described require no special skill and almost no apparatus. The few articles required will also serve for many other experiments. The necessary plants can all be grown on a single shelf in front of a convenient window. In this brief space I can mention only a few experiments, merely enough to give an idea of

the method. But it is the method upon which I desire to lay stress, since experiments are often performed in such a way as to be a source of confusion rather than of inspiration.

The Seed.

We shall do well to begin where the independent life of the plant begins, with the seed. Plants should be used which are familiar to everyone, and which are easily grown and cared for. Some Scarlet Runner Beans may be soaked over night and given the children to examine, together with unsoaked seeds for comparison. How does soaking affect the covering of the seed? Do all seed-coverings* behave in this way? Try some hard, resistant ones, such as the Castor Bean, Buckeye, Acorn, and Peach or Cherry pits. Of what use is the seed-covering? Does it help the taking up of water? A simple way to answer this is to remove it before soaking and note the result as shown by the general appearance of the seed. Acorns are good for this purpose as the shells are easily removed and the seed is usually more or less shrunken and becomes plumper on taking up water, so that the effect can be easily noted. How does the water get through the seed-covering? Select some well-soaked Scarlet Runner Beans. Wipe them perfectly dry on the surface. Now squeeze the seed. Does water ooze out? Where? Does this hole in the seed-covering allow water to enter? Can you find it in other seeds? Can water get into the seed except through this hole?—Take some unsoaked seeds. Fasten them in a piece of split cork so that when it floats in the water the seeds will be half submerged. Let the hole in the seed-covering be well above the water and take care to keep it perfectly dry. If the seed takes up water in this position it must be through the seed-covering itself. It is interesting to use seeds with hard coverings for this experiment, and to fasten some in the reverse position, with the hole under water, as a control-experiment.

The Awakening of the Plant.

Within the seed-covering is a tiny, sleeping plant.

*The term seed-covering is here used to include both seed-coats proper and other coverings from whatever source derived.

Notice its tiny leaves, radicle and seed-leaves (Fig. 1).

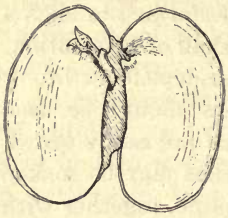

Fig. 1.*

When does it waken? What is necessary to make it germinate and grow? Place some soaked seeds in damp sawdust and keep one lot on ice and another in a warm place. Place some unsoaked seeds in dry sawdust, and keep others immersed in water which has been boiled for the purpose of expelling the air and then allowed to cool. On the top of the water a film of oil may be placed to prevent absorption of air. Which lot of seeds germinates? What prevents the others from doing so? Water, air, and a certain amount of heat are necessary to awaken a plant from its sleep. How long will plants keep alive waiting for a chance to germinate? Do some seeds respond more quickly than others when the right time comes? Is this an advantage to them? When a plot is sown for a lawn, what plants come up first, the grass or the weeds? Are weeds apt to be quick starters? Does this help to explain their success in crowding out other plants? We should remember that there is a constant struggle going on among plants for light, because if a plant be shaded too much it cannot live. The plants also crowd each other and struggle for room both above ground and below, where the interlacing roots are eagerly competing for the nourishment in the soil.

Getting out of the Seed-Covering.

When the awakened seed starts to grow, it must first get out of its imprisoning seed-covering. When the covering is tough and hard, it requires considerable exertion to get out. Notice how the seed swells. Does it exert much force on the seed-covering in swelling? We can gain some idea of this if we put as many seeds as we can into a thick-walled bottle and immerse it in water over night. When morning comes the bottle will be found in fragments. Occasionally a ship, laden with rice or grain, founders or runs aground where the waves break over her, and the swelling seeds burst her in pieces just as they do the bottle.

*All drawings were made from nature by Mr. A. A. Lawson.

In the Scarlet Runner where do we find the first rupture of the seed-covering? Is there any reason for its occurrence in this particular spot? Remember that the radicle and the hole in the seed-covering are both found here. Is this so in all seeds? Is it any advantage to the radicle to double itself up as in Fig. 2A? Why? Notice how it behaves as soon as it is free (Fig. 2B). What part of the seed grows most rapidly? Do the seed-leaves grow at all? What has split the seed-covering across in Fig. 2B?

FIG. 2A.

FIG. 2B.

Notice how hard are the coverings the little plant must break through in the Buckeye, the Peach, and the Cocoanut. Would it not be a great advantage if the covering were made softer or less resistant at the spot where the plant must break through? Can you discover anything of this kind? The "eyes" of the cocoanut are softer places in the shell; the peach stone splits easily along the edges. Peach stones take so long to germinate that we will study the squash instead. Notice where the seed splits (Fig. 3); notice also a peculiarity of the squash, a small projection known as the "peg" which grows out just at the right place on the stem. Can you see of what use this peg is? To watch a squash wriggling out of its shell reminds one of the way a man pulls off his boots, and the peg corresponds to the man's toe when he makes it serve as a bootjack (Figs. 3 and 4).

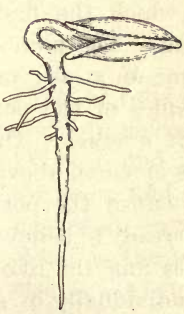

FIG. 3.

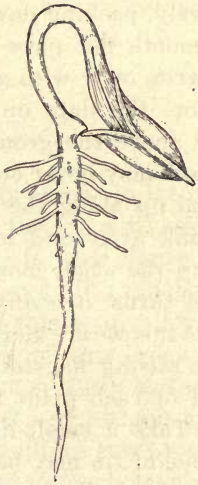

FIG. 4.

Getting into the Ground.

As soon as the plant is fairly out of the seed-covering, the root begins to bore its way downward into the soil. Have you ever noticed what a hard time the roots have in getting into the ground when the seed happens to lie on the surface? Put some seeds on the surface of moist soil and cover them with a funnel (with a little cotton-wool in the neck to retain the moisture and admit air) or with an inverted wide-mouthed bottle, or, better still, with a bell jar. At first when the root starts to bore downward into the soil it only succeeds, in many cases, in lifting the seed up from the earth. How does the plant overcome this difficulty? If you look closely you can see a host of tiny thread-like hairs growing out from the radicle and anchoring the plant to the soil, thus enabling it to penetrate into it.

Getting above Ground.

Have you ever thought of the difficulties plants have when the seeds are buried deeply underground and on awakening and bursting their seed-coverings they find a load of earth, which must be struggled through or pushed aside before they can reach the light? Should you think this would be a serious obstacle to overcome? Plant some Scarlet Runner Beans in three different pots, one, two, and three inches deep respectively, packing down the earth well above them. Thrust a smooth flat piece of wood into the soil beside each lot and write on it with a soft lead pencil the date of planting. Note the date on which the first plants of each lot appear above the ground. The plants which are deepest in the soil may never come up at all; or if they do, they may creep up along the sides of the pot where the earth has shrunk away and left a crack. Or sometimes they will lift up the whole mass of earth above in a round, solid cake and thrust it bodily out of the pot. After witnessing a feat like this we are more ready to believe in the tales of mushrooms raising flagstones and the like. We may test the strength of each plant individually by a very simple contrivance. Take a small light glass funnel (if this proves too heavy one of tin may be used), close the end with a cork and thrust the neck through the bottom of

a small pasteboard or paper box. This should be placed over the plant as it emerges from the ground, and shot may be poured into the box until the plant is barely able to raise the load.

Notice how much more easily some plants come up through the ground than others; the Corn-plant, for instance,

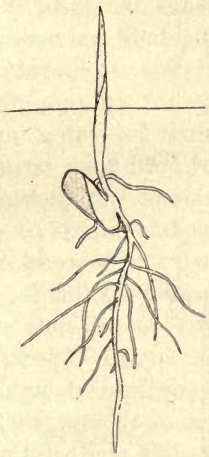

FIG. 5.

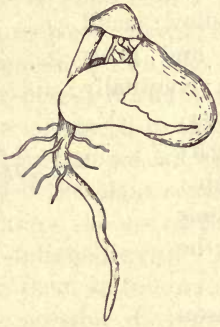

FIG. 6.

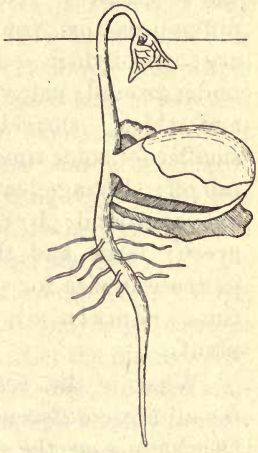

FIG. 7.

(Fig. 5) rolls its leaves up into a sharp, slender awl which seems to pierce the soil with ease. But the Scarlet Runner (Figs. 6 and 7) is very clumsy on account of the crook in the stem, and must lift a much greater load. Sometimes it pushes up great lumps of soil when it comes to the surface. What is the use of this crook in the stem? Let us look also at the common Bean and at the Castor Bean (Fig. 8), which do not get out without a struggle which reminds us of an athlete straining every muscle. Can you tell why the Castor Bean has so much trouble?

Seed Leaves and Foliage Leaves.

Let us now notice what the plant does when it gets above ground. The Scarlet Runner straightens out the crook in its stem and points its tip straight upwards. Soon the new leaves grow larger and we see clearly that they are not at all like the seed-leaves. Notice all the differences that you can. Here are some of them:—Seed-leaves: underground; pale yellow; small and thick; shrivel and grow smaller for some time, eventually fall off. Foliage-leaves: above ground; bright green; large and thin; increase in size for some time, remain on the plant.

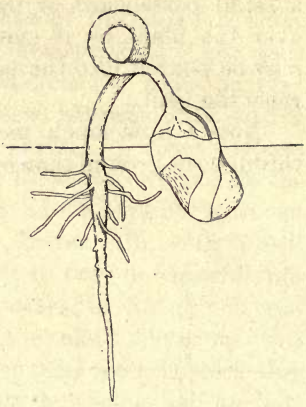

FIG. 8.

The Work of Seed Leaves.

What is the reason for all these differences? Of what use are the seed-leaves? Perhaps the simplest way to answer this is to cut them off and see how the plant gets along without them. Select several plants (about an inch high) growing in a pot. Remove the seed-leaves from one-half the number and tie pieces of white twine to the uninjured plants and red twine to the others, to

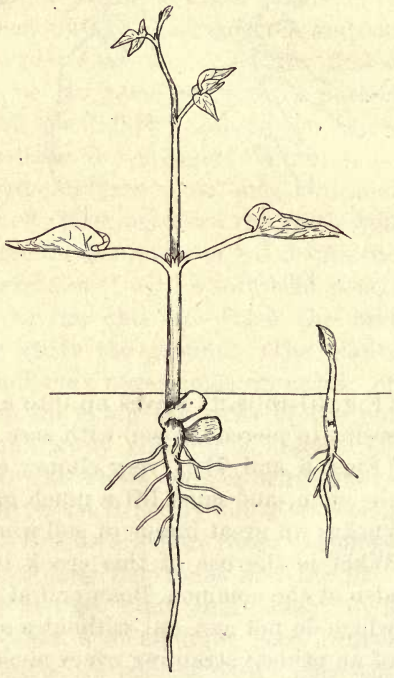

FIG. 9.

distinguish them. In a few days you will see a difference; later on this will be much more marked (see Fig. 9). It would seem that the loss of the seed-leaves stops the growth of the plant. Why is this so? We see that the longer the seed-leaves remain on the plant the more they shrivel; *i.e.*, the more substance they lose. We cannot help thinking that the plant is taking this substance from the seed-leaves, especially when we find that the principal substance in the seed-leaves is starch, a very important food-substance for plants. How do we know this substance is starch? By means of a very simple test which you may try for yourselves. Break a seed-leaf in two and put a drop of iodine solution on the broken surface; if it turns dark blue (or black) it shows that starch is present. Test a little commercial starch in the same way. This test is so simple and certain that we can use it whenever we wish to know if any part of the plant contains starch.

The Work of Foliage Leaves.

I think we now know the use of the seed-leaves. What is the use of the foliage-leaves? Do they also contain starch? Let us test them as follows: Let the plants stand in as strong light as possible during the day; toward sundown remove some of the largest leaves, boil them (in order to kill them and swell the starch) and put them in alcohol over night. In the morning they will appear bleached, as the alcohol has extracted the green color. Dissolve in water some crystals of potassium iodide and add a few flakes of solid iodine to the solution. Place the leaves in the solution and if they do not turn dark at once leave them for some hours.

How do the foliage-leaves get their starch? Do they get it from the supply in the seed-leaves, or do they make it themselves? Let us see if we can answer this question. Keep a plant in darkness two or three days; test the leaves for starch. If none is found, remove several leaves from the plant, putting one-half the number in darkness for a day or two and the rest where they will get as much light as possible. The leaves must be placed in water; be sure

that the stalks dip well beneath the surface. After a day or so test the leaves which have been in the light. The starch which we now find in the leaves must have been made by them *after they were removed from the plant.* Now test the leaves which have been kept in darkness all the time. Why is there no starch in them? Is it because they have been kept in darkness? We may put this to a final test in a very simple way. Fasten corks to opposite sides of a leaf, (as shown in Fig. 10) so as completely to exclude

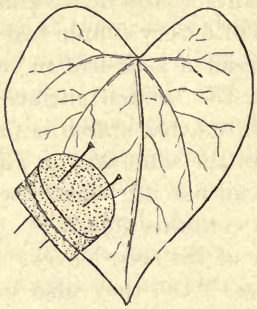

FIG. 10.

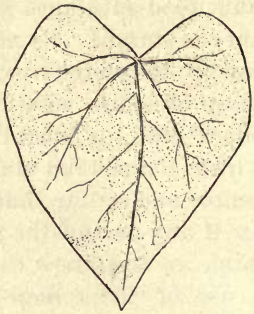

FIG. 11.

the light from the covered portion. The leaf must not be removed from the plant and should be placed where it will get plenty of light. In a day or so test it for starch; this is found everywhere except in the covered portion (Fig. 11). It would seem that lack of light alone has prevented this part of the leaf from making starch. Foliage leaves, then, have the power of making starch; but they must have light in order to do so.

Now what is the use of this starch in the foliage-leaves? Is it absorbed by the plant like the starch in the seed-leaves? If so, ought we not to find less starch in the leaves in the morning than at night, since the making of starch stops at sundown and what is taken away during the night cannot be replaced until the next day? Test some leaves at sundown or a little before; now place the plant in a dark box or cupboard, and in the morning test again. We find the starch

has almost or quite disappeared. Would it have done so if the leaves had not been on the plant? Take some leaves which contain plenty of starch; remove them from the plant and put them in a dark box or cupboard. The stalks should dip well under water. In a day or so test them for starch. They have not lost any. It seems then that *foliage leaves produce starch and the plant absorbs it from them.*

It is now time to see whether we can answer the question asked a little while ago, Why are the foliage-leaves and seed-leaves so different? You can see that it is of advantage to the plant to have the foliage-leaves remain as long as possible on the plant. You can also see why they should have as large a surface as they can, since the more light they catch the more starch they can make. You can see, too, why the seed-leaves need to be thick and bulky so as to store up a great deal of starch. Perhaps you do not see why the foliage-leaves are green and the seed-leaves pale yellow. You will understand this if you put a few seeds into a pot containing soil or sawdust and keep it entirely in the dark until the plants are several inches high. The plants grow very tall and slender and the leaves are small and yellow, in color resembling the seed-leaves. Put the plants in the light for a day or so. Test them for starch. None is found. Leave them in the light until they turn green. Then test for starch. Does the result indicate that the green substance is necessary for making starch? It is this substance, called chlorophyll, which is extracted by the alcohol when you test the leaves for starch. Usually it is not formed in darkness. Do you now see why the seed-leaves are not green? Remove some of the earth so as to expose them to the light. Do they turn green?

The seed-leaves and foliage-leaves are different because they have different tasks to perform, and their structure must be adapted to the special kind of work they have to do. We may sum this up by saying, *function determines structure.* When we see how different the seed-leaves of

the Castor Bean are from those of the Scarlet Runner, for example, we at once suspect that their tasks must be quite different. Notice how thin and delicate are the seed-leaves of the Castor Bean (Fig. 12). Where is the food stored in the Castor Bean? Not in the seed-leaves but around them, and their task is merely to absorb it. See how closely they are attached to the substance they are absorbing. Cut away the food substance carefully, so as not to injure the seed-leaves. Does this check the growth of the plant? After the seed-leaves get above ground they are called upon to do still another kind of work. What is it? Do they change their appearance correspondingly? (See Fig. 13). Do you know any other seed-leaves which are absorbing organs instead of storehouses—any which are both? (See Fig. 5). Do you know any other seed-leaves which come above ground and help to make starch?

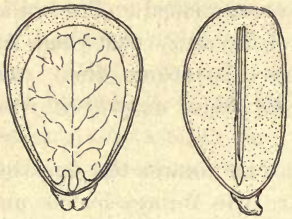

Fig. 12.

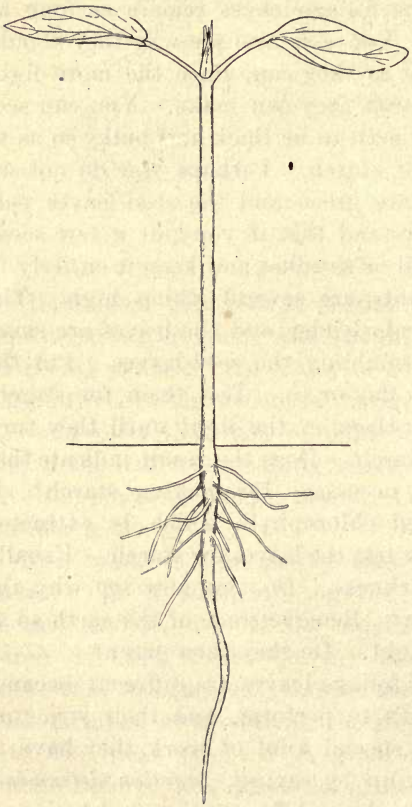

Fig. 13.

The Work of the Root.

Every part of the plant has its work to do and its whole structure is expressly adapted to this work. Notice the root, for instance. See the multitude of tiny hairs which help it to absorb water and food. Where the root is covered with these hairs the absorbing surface is ten to twenty times as great as elsewhere. Notice the root-cap which protects the delicate tip as it is driven downward into the soil. (Roots allowed to develop between pieces of moist blotting paper show the hairs well; cuttings of Wandering Jew placed in water develop roots which show both the cap and the hairs admirably). Is the root driven down into the soil with much force? We may find out by a very simple contrivance. Remove the top and bottom from a shallow wooden box. Replace the bottom by wire-netting with meshes about one-quarter of an inch square. Cover this with a piece of tin-foil and on this place enough earth to fill the box. Place seeds in this and suspend the box at a convenient height so that when the roots come through the bottom they can be easily observed. How thick a piece of tin-foil will they penetrate? Try different kinds of seeds.

How Roots and Stems Grow.

What drives the root downward with so much force? Why are not the side roots torn off as the root moves downward? We may answer both these questions by marking a root with ink-dots (waterproof ink is best; it should be put on with a small brush) about one-sixteenth of an inch apart and allowing it to develop in water.* We shall then see the marks separate near the tip, showing that the root is elongating there, while higher up is a region where they do not separate. It is only in this upper region that the side roots come out.

Does the stem have a similar elongating region? Where are the new leaves formed? What would happen to the stem if this elongating, formative region were removed? Select Scarlet Runner seedlings about two inches high

* Tie a piece of cheese-cloth over the mouth of a tumbler; thrust the root through it; pour in water until the seed-leaves are partly submerged and invert a second tumbler over the first.

(above ground) and cut off the stem below the first pair of foliage-leaves. In a few days you will see new stems or branches starting out. Where do they appear to come from? (See Fig. 14). In a short time these will be followed by others until a dozen or more are growing up to take the place of the one which has been removed. Try the same experiment on other kinds of plants. Now let us remove the elongating region of the root and see what will happen. Do new roots come out? Where? Do they grow horizontally like the side roots or straight downward like the main root? The roots should be allowed to develop in water so as to be easily observed.

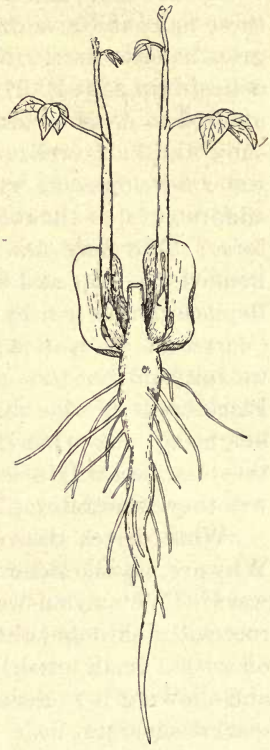

FIG. 14.

Why the Root Grows Downward.

Does the main root always grow straight downward? Try placing the seed in various positions to see if this affects the direction of growth. The seeds may be placed on the surface of moist earth (and covered as described above) or may be pinned on corks in various positions, and the corks may float on the surface of the water in a shallow dish. A little cotton laid over the seed-leaves and dipping in water will keep them moist. After the root has grown a little, change the position of the seed so that the root points straight upward or is horizontal. Does it begin to grow down again? Why does the main root persist in growing downward no matter in what position the seed may be placed? The idea has been put forward that the root tip not being very rigid droops downward of its own weight, and this starts the growth in the right direction. This

idea can be tested by a very simple experiment. In a small glass dish place some mercury; split a cork and fasten it to the side of the dish (Fig. 15). To this pin a germinating seed with a perfectly straight radicle about an inch in length. Place the radicle in a horizontal position and resting on the surface of the mercury. Pour on enough water to partially submerge the seed. In a few hours the root-tip will bend downwards and penetrate the mercury, overcoming its resistance (Fig. 15).

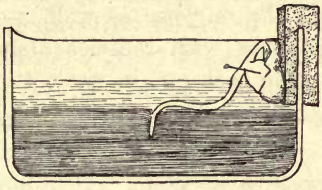

FIG. 15.

It would seem that gravity must determine the downward growth of the root. Now, if this be so, what would happen if we make the force of gravity of no effect by placing the seed on a revolving wheel? If the wheel turns always at the same rate, each side of the root will feel the downward pull of gravity for a short time, but no side will feel it more than another. So when all sides are equally affected, will the root have any tendency to bend in one direction more than another? Let us see. The construction of the wheel is a very simple matter. Have a plumber or tinsmith cut out of thin sheet zinc a circular piece six inches in diameter. Have this cut to allow the insertion of corks as shown in Fig. 16. Let the flaps made by cutting remain in place. Fix round, flat corks in the cut places, and bend the flaps so as to support the corks as firmly as possible. For the axle use a knitting needle, impaling two rubber corks upon it, one on each side of the zinc disc (Fig. 16, A) to hold the latter in place. They should press firmly against the disc to insure its turning with the axle. Two upright wooden supports fastened to a block of wood are pierced by holes just large enough to admit small glass tubes in which the axle rests. One of these (Fig. 16, C) is closed at one end to keep the axle from slipping too far; the other (Fig. 16, B), being open at both ends, allows the axle to pass through, and (being bent at a right angle as shown in

the figure) to be fastened by fine wire to the minute-hand of a clock. This apparatus, which almost anyone can easily make in a little while, permits of some exceedingly interesting experiments, and answers the purpose as well as a costly instrument. Select some peas with radicles about half an inch long; partially envelop each one in wet cotton

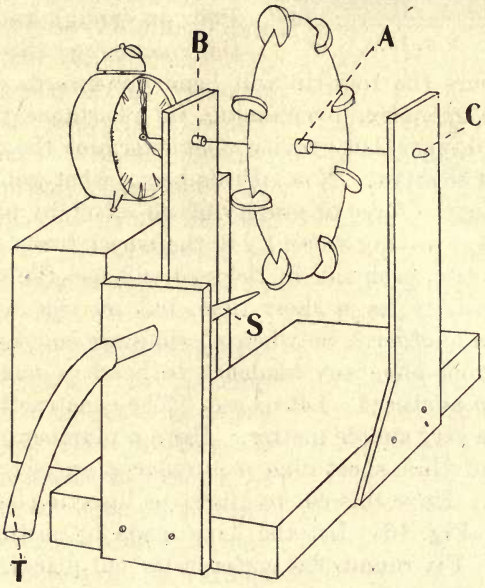

FIG. 16.

and pin them upon the corks. Arrange a saucer of water so that as the wheel revolves the seeds will dip into it and be kept moist. The seed itself need not come in contact with the water, but a little strip of cloth or filter paper may be arranged so as to hang down from the seed and touch the water. The clock is set agoing and the wheel revolves once an hour. The seeds grow well under these conditions, but the direction of growth is no longer the

same for all the roots. Instead they may grow in almost any way. Often we see some of them turn and grow in the same direction as the stem. How do the stems behave? The directing power of gravity being removed, both stems and roots grow in quite haphazard fashion.

We may now go a step further and substitute a new force for that of gravity. This we may do by making the wheel revolve more rapidly. If you bend a piece of wire around the spoke of a wheel, so as to form a loose ring, and spin the wheel rapidly, the ring will be violently hurled to the rim of the wheel by a force commonly called centrifugal force. If the wheel be revolved rapidly enough the centrifugal force will be much greater than the force of gravity. Will a seed placed on such a wheel direct its roots in accordance with the centrifugal force? To test this we remove the clock and saucer, place the apparatus in a sink, and attach the rubber tube, T, to a faucet. At the end of this tube is a piece of glass tubing, S, drawn to a point. The manner in which this is supported is shown in the figure. It should be wedged firmly in place by wooden wedges, and be directed so that the stream will strike the wheel just at its rim. The stream must be powerful enough to make the wheel revolve rapidly. A piece of cloth must be put over and around it, like a tent, to confine the flying drops. In the course of a day or so, provided the wheel is turning rapidly enough, we shall see the roots all bending away from the center of the wheel and growing straight out in the direction of the radius, while, on the other hand, the stems grow straight in, pointing their tips toward the center of the wheel.

Let us see what will happen if we place the apparatus on its side so that the wheel revolves horizontally, the closed tube, C, being below. If the plants have become inconveniently large we may replace them by fresh ones with radicles about an inch long. Two forces now act on the plants, the centrifugal force and that of gravity. The roots take up an intermediate position, growing away from

the center of the wheel as before, but also obliquely downward; the stems grow in an exactly opposite direction.

These experiments lead us to think that when the root and stem issue from the seed, gravity determines the direction in which they grow. And so we can understand how the seed, whether above ground or below, unerringly sends its stem and root in the right directions. We can easily understand that this is a very important matter for the plant, for the quicker it gets its stem above ground, into the light and air, and its roots down into the soil to find food and moisture, the better will be its chances of living through this first period of its independent life, which is more critical and beset with dangers than any other.

Do Roots Seek Water?

The root goes down into the ground to seek for water. Sometimes we find drains or cisterns choked by roots which have grown into them from trees many yards away. This leads us to suspect that roots seek for water. Can you think of any way to test this idea? Here is a very simple one, but you may think of one equally good. A glance at Fig. 17 will explain it. The seeds have been

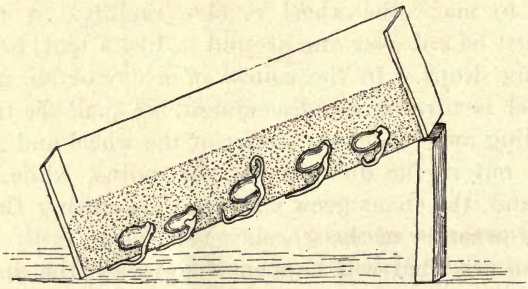

Fig. 17.

planted in damp sawdust, in a box with a bottom made of wire-netting. The roots, growing straight down at first, meet the dry air and turn back, some of them at least, to

the damp sawdust. In this case moisture seems to be more powerful than gravity in directing their growth, and we can readily see that this is of advantage to the root, since its function is to seek and absorb water.

Do Stems Seek Light?

Now the stem goes above ground to seek light. Does it have the power of growing toward the light as the root does toward moisture. Can you think of a way to answer this question? The easiest way is to cover the plant and the pot in which it is growing with a box, and make a hole at one side to admit light. Then if the plants have any tendency to grow toward the light, it ought to show itself.

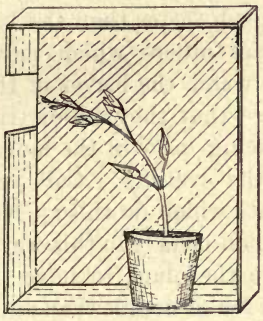

Fig. 18.

The result of this experiment is shown in Fig. 18; in this case a Scarlet Runner was placed in a wooden box, one side of which is removed to show the plant. Radishes are good for this experiment. They come up quickly and are very sensitive to the light. We must not forget that the whole object of seeking light is to expose the leaves to it. In what position will they catch the most light? Do you generally find leaves in this position? Observe all the plants you can out of doors to see how their leaves are placed. Notice especially plants growing near walls or houses, or in any position where they get the light from one side only. Do you find the leaves facing the side from which the light comes? Is this arrangement due to the light itself? Grow some Nasturtiums in pots and place them in a box which admits the light on one side only. When the leaves have all turned so as to face the light, turn the plant around so that they face away from it. How long is it before they begin to turn back again? Try them before a window in the same way.

Do Leaves Seek Light?

The English Ivy (Fig. 19) is interesting to experiment with; but it takes too long to grow it in pots, so we will use a quicker method. Find some plants growing where they get plenty of light, and bending back some of the branches tie them so that the side that was shaded before now gets the light. How do the young leaves place themselves? On which side do the new roots come out? Where do the new leaves appear? Does this indicate that light influences roots as well as stems and leaves? The Nasturtium leaves turn to the light much faster than the Ivy leaves, but there are others which move still faster. If you watch the leaves of the Lupine, you will see that they follow the sun all day long, facing east* in the morning and west* in the evening. Can you find any other plants which do this? Are there any flowers which behave in this way?

FIG. 19.

It must be a great advantage to the plant to have its leaves following the sun in this way, for of course they must get much more light. But most plants must be content to have their leaves remain in one position, or at least move very slowly indeed. It is, then, all the more important to have the leaves placed in the most favorable way possible. If they are crowded one above another, they will keep each other from getting the light they need for making starch. Can you find any indications of a skillful arrangement for avoiding this? Look at a branch of the Chestnut (Fig. 20) or Ivy-leaved Geranium (Fig. 21) and notice how the leaves are placed. Do they shade each other? This arrangement has been called a leaf-mosaic. Do you see why? Can you explain how this clever arrangement is brought about? What are the best leaf-mosaics you can find?

i.e., Northeast or -west, or southeast or -west, according to the season.

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FIG. 20.

FIG. 21.

A Life-long Inspiration.

We have scarcely made a beginning of our experiments, yet they have already led us into the fields to study plants as we find them. Here there is always something of interest for eyes which have learned to see. With a little guidance the child learns to see more and more for himself, and strives more and more to see aright, to draw and describe things as they really are. So the love of nature leads him to the love of truth. These twin influences, upbuilding both mind and character, should come early to the child and be a lifelong inspiration.

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